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# GEOGRAPHICAL DISTRIBUTION; ORIGIN OF THE BERMUDIAN DECAPOD FAUNA

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IN a report now in course of publication[1] on this group, 78 species, subspecies or named varieties are discussed, of which 16 have not been previously recorded from Bermuda. Among these, six are described as new.

Of the total number, 72, equal to 93 per cent., have been recorded also from the Florida Keys or the West Indies, or from both, demonstrating the close faunal relations of the two regions. The macruran Decapoda (35 species) show similar relations.

About 53 of the forms (about 68 per cent.) range from Florida to Pernambuco, Brazil, or farther south.

A considerable number, about 25 species, or 31 per cent., extend their range north of Florida to the coast of South Carolina or farther north, the greater portion of these reaching Cape Hatteras. Six or seven reach southern New Jersey.

Two species, *Callinectes sapidus, Eupanopeus Herbstii* and its var. *obesus,* range northward to southern New England, as permanent residents.

Several others occur occasionally or sporadically on this coast, being carried northward by the Gulf Stream, or by shipping, but fail to become naturalized so far north, owing to the cold of winter.

[1] *Trans. Conn. Academy of Sciences,* Vol. XIII, pp. 299–473, plates ix–xxviii.

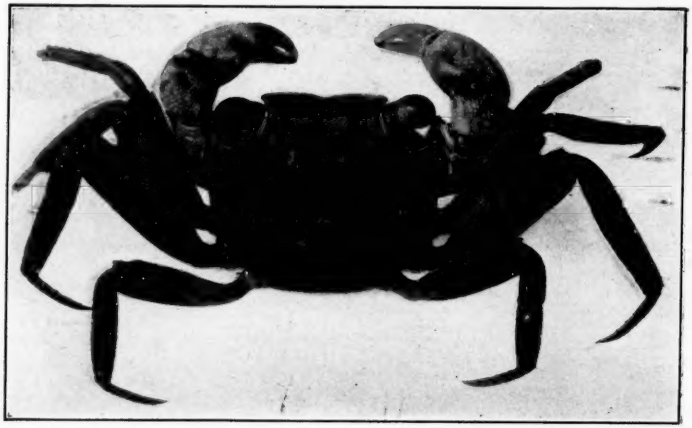

FIG. 1. *Sesarma Ricordi*, var. *terrestris*, nov. Co-type; × about 2. Phot. A. H. Verrill.

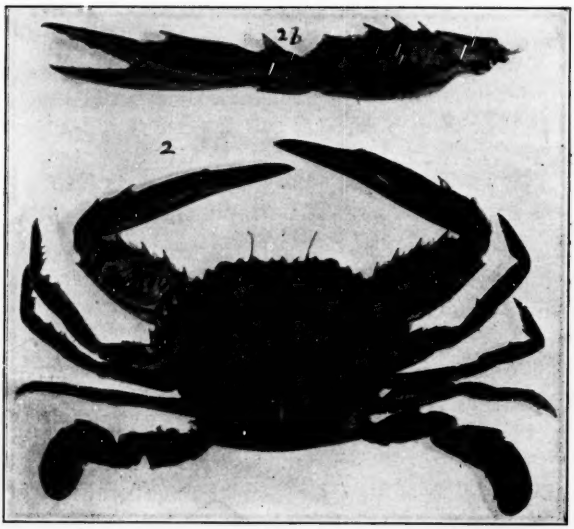


FIG. 2. *Achelous Smithii*, nov.; cotype, dorsal view; × about 1 1/10; 2b, chela of the same, front view. Phot. A. H. Verrill.

It is evident, therefore, that the Bermuda decapod crustacean fauna is an offshoot or colony from the West Indian fauna, with only a slight admixture of species from other regions. In this respect the Crustacea agree with the Anthozoa, Mollusca, Echinoderms, etc.

The additions to the fauna of Bermuda, including the new species and varieties, are as follows:

* *Sesarma Ricordi, terrestris,* subsp. nov. See *Science,* Vol. XXVII, p. 491. Fig. 1.

* *Eupanopeus Herbstii, minax,* subsp. nov.

* *Eupanopeus bermudensis,* var. *sculptus,* nov.

*Callinectes Danæ* Smith.

*Callinectes marginatus, larvatus* (Ord.).

*Achelous Smithii,* nov. Fig. 2.

*Achelous Gibbesii* Stimpson.

*Charybdella tumidula* (Stimpson).

*Mithrax cornutus* Saussure.

Challenger Bank, 30 fathoms. Field Museum Nat. Hist., 1905.

*Parthenope* (*Platylambrus*) *crenulatus* (Saus.). Fig. 5.

Challenger Bank. Bermuda Biological Station, 1903.

*Troglocarcinus corallicola,* gen. et sp. nov. Fig. 3.

Parasitic in living corals (Mussa, Mæandra).

*Dromia crythropus* (Edw). Fig. 7.

Argus Bank, 30–40 fathoms. Field Mus.

*Dromidia antillensis* Stimpson. Fig. 4.

Challenger Bank. Bermuda Biological Station, 1903.

* *Petrolisthes armatus, pallidus.* var. nov.

* *Munida Beanii,* sp. nov.

Argus Bank, 50 fathoms. Field Mus. Nat. History.

*Dardanus venosus* (M.-Edw.).

Previously recorded under the name of *D. insignis,* which is a distinct species.

* *Clibanarius hebes.* sp. nov.

Those with an asterisk prefixed are known only from Bermuda.

The following 25 species range northward on the American coast to or beyond South Carolina, as permanent residents:

*Ocypode arenarius.* (To N. Jersey.)
*Planes minutus.* (To N. Jersey.)
*Plagusia depressa.*
*Portunus Sayi.*
*Achelous anceps.*
*A. Gibbesii.*
*A. spinimanus?*

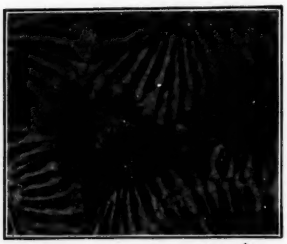

FIG. 3

FIG. 4

FIG. 3. *Troglocarcinus corallicola*, nov., ♀, partially out of its den in a coral (*Mussa*) from Dominica I; × about 2. The crab was intentionally placed in a den belonging to an older individual, otherwise but little of it could be seen. Phot. A. H. Verrill.

FIG. 4. *Dromidia antillensis;* about nat. size. Phot. A. H. Verrill.

*Cycyloxanthops denticulatus.*
*Eupanopeus Herbstii.* (To C. Cod.)
*E. Herbstii. obesus.* (To C. Cod.)
*E. occidentalis.*
*Eurytium limosum.* (To N. Jersey.)
*Eriphia gonagra.*
*Callinectes ornatus.*
*C. sapidus.* (To C. Cod.)
*A. Smithii,* nov.
*A. Sebæ.*
*A. Ordwayi.*
*A. depressifrons.*
*Stenorhynchus sagittarius.*
*Podochela Riisei.*
*Mithrax forceps.*
*Macrocœloma trispinosum.*
*Calappa marmorata.*
*Petrolisthes armatus.*

FIG. 5. *Parthenops crenulatus;* × about 3. Phot. A. H. Verrill.

Several of the species, mostly grapsoids, are found in most, or all, tropical seas, as well as in the West Indies. They are as follows:

*Grapsus grapsus.*
*Geograpsus lividus.*
*Plagusia depressa.*
*Percnon planissimum.*

*Pachygrapsus transversus.*
*Planes minutus.*
*Domecia hispida.*
*Petrolisthes armatus.*

Nearly all the widely distributed species, included in the last list, are found on the West Coast of Africa. But some additional species, common to Bermuda and the West Indies, are also found on the West African coast. Namely:

*Goniopsis cruentatus.*
*Callinectes marginatus ? larvatus.*
*Stenorhynchus sagittarius.*
*Calappa marmorata.*
*C. gallus, galloides.*
*Hippa cubensis.*

Aside from the widely distributed grapsoid crabs, found in all tropical seas, very few of the Bermuda species are found on the Pacific coasts of Central and North America. But some others are represented there by closely allied species or subspecies. The species that have been considered identical by recent good authorities are as follows:

*Goniopsis cruentatus.*
* *Grapsus grapsus.*
* *Geograpsus lividus.*
* *Pachygrapsus transversus.*
* *Planes minutus.*
* *Plagusia depressa.*
* *Percnon planissimum.*
* *Domecia hispida.*
*Epialtus bituberculatus* (varieties).
* *Calappa gallus* (varieties).
*Cycloës Bairdii* (varieties).
. *Petrolisthes armatus.*

Those preceded by an asterisk are circumtropical.

It is well known that a considerable number of species of Mollusca, Echinoderms, Anthozoa, etc., as well as Crustacea, are common to West Africa, Brazil and the West Indies. Such species may have originated on the African coast and thence migrated across the Atlantic to South America, and thence northward to the West Indies, Florida and Bermuda, during recent geological times. All the species of Decapod Crustacea having this wide range exist for a considerable length of time as free-swimming larval forms, in the zoëa and megalops stages. These larval forms may be carried long distances by the prevailing oceanic currents, especially in the regions of the trade winds.

It is scarcely admissible to suppose that they could have

traveled in the opposite directions, against the currents, unless by human agency, in recent times.

Many Crustacea, including the higher and more active forms, especially the grapsoid and cancroid crabs, are in

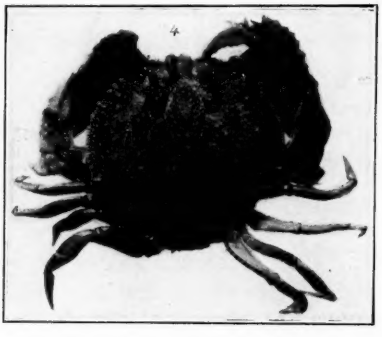

FIG. 6. *Cyclocs Bairdii*, var. *atlantica*, nov., $\frac{5}{13}$ nat. size. Phot. A. H. Verrill.

the habit of hiding among the clusters of barnacles, etc., attached to the bottoms of vessels, and in this way they may be carried across the oceans in any direction, so long as the temperature of the water is suitable for their existence. In this way many tropical species reach the New England coast in summer, but die out during the winter.

Several species of crabs and shrimps habitually live among floating *sargassum*, or attached to floating drift-

FIG. 7.. *Dromia erythropus* from Dominica, with a flat Chalinid sponge held over its back, about ½ nat. size. Phot. A. H. Verrill.

wood. This is the case especially with *Planes minutus*, *Portunus Sayi*, and some others. That they have migrated to Bermuda in this way is very evident, for they do so constantly, day by day, at the present time.

But the majority of the species common to Bermuda and the West Indies do not have such habits, and must have migrated northward in the free-swimming larval stages. The directions of the Gulf Stream and prevailing wind currents are favorable for the transportation of free-swimming animals from the Bahamas, Cuba, etc., to the Bermudas.

On the other hand, very few, if any, strictly East American species have established themselves in the Bermudas, notwithstanding the constant passage of vessels in that direction for nearly three hundred years. Perhaps the temperature of the Gulf Stream is too high to allow such species to be carried across it, or they may not be able to endure the summer temperature of the Bermuda waters.

There are, likewise, no Decapod species of European or Mediterranean origin known in the Bermuda fauna, though such are known to occur in other orders, especially in those groups that habitually cling to the foul bottoms of vessels.

It would be of great scientific interest, as well as evident economical benefit, to experiment with the introduction of edible East American and West Indian crustacea that do not now exist at the Bermudas. Among those that might succeed are the large southern rock crab (*Menippe mercenaria*); the West Indian rock crab (*Carpilius corallinus*); the southern variety of the edible blue crab (*Callinectes sapidus*); and many others. Probably their fertilized eggs could be transported far more easily than the adults, and in vastly greater numbers. With suitable arrangements at the new Bermuda Biological Station, such eggs could easily be hatched and the young liberated in great numbers, in suitable places.

It would probably be useless to attempt to introduce those species that are restricted to our coast north of

Cape Hatteras, such as the common lobster, but there seems to be no reason why any species from the Carolina coasts or the Florida Keys should not flourish in Bermuda if once introduced there in considerable numbers and protected from their enemies at first.

Probably hundreds of species have been accidentally carried there, singly or in small numbers, in past times, which have failed to establish themselves, either because they became too far separated to find their mates at the breeding season, or because they were too soon eaten up by voracious fishes. Yet a single female crab, carrying fertilized eggs, might succeed in introducing the species, for their eggs often amount to 5,000, or even 10,000 at one time. Aside from edible species, the introduction of the smaller kinds would afford a large additional supply of food for useful fish, and thus benefit the fisheries.

# ON THE INTERPRETATION OF CERTAIN TROPISMS OF INSECTS [1]

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THE great interest which has developed among zoologists during recent years regarding the behavior of animals has resulted in such a large number of papers on tropisms and related topics, that a short discussion of the matter in regard to insects may seem rather uncalled for at present.

The field of entomological research affords, however, so many possibilities in this line that the activity which was formerly confined to studies of lower invertebrates is gradually showing a tendency to shift or to widen out toward the insects in its search for fresh subjects, and already the reactions of various species belonging to several groups have been investigated by the commonly accepted methods. The problem of studying the responses of insects to light, gravity, mechanical stimuli, etc., involves so many factors which do not enter into any consideration of simple organisms like protozoa or planarians that its complexity is rarely appreciated by those who give it their attention. The former animals can be brought into the laboratory and placed where the normal conditions of their natural environment are reproduced more or less faithfully. Under such circumstances their reactions and behavior can be analyzed by means of different mechanical contrivances which have been devised to test the influence of certain stimuli to the exclusion of others. To be brief, experience has shown that conclusions derived from such experiments are fairly trustworthy, and that a close approach can be thus made

[1] A paper read before the joint meeting of the Wisconsin Academy of Sciences, Arts and Letters and the Wisconsin Natural History Society at Milwaukee, February 13, 1908.

to an understanding of the animals' behavior in their natural environment. The extension of these methods into the study of such highly specialized and delicately organized invertebrates as insects is fraught by many dangers, and the failure to recognize certain inherent difficulties must inevitably invalidate some of the general conclusions which have been recently announced.

Without reference to the psychological aspect of insect behavior which I am in no way competent to consider, there are a number of factors entering into the study of reactions which I believe must be recognized if we are to appreciate the fundamental difference between a natural environment and an artificial reproduction of its single features in the laboratory.

Probably more experiments on insects have been recorded which bear upon the phenomena of phototropism than upon any other single tropism, and we may therefore reasonably suppose that the results in this field represent actual conditions as well as, if not better than, those on other tropisms.

Turning to a recent paper by Frederick W. Carpenter on the reactions of the pomace-fly, *Drosophila ampelophila,* to various stimuli,[2] we see the statement:

"Light has both a kinetic and directive effect. The insect moves toward the source of light, being positively phototropic. The directive effect is apparent only when the kinetic stimulus is sufficient to induce locomotion."

This is merely a concise expression of the fact which we have all observed many times of the fly buzzing on the window. Under such conditions most Diptera are positively phototropic and will go through long series of alternating periods of activity and quiescence, the former usually induced by some external stimulus; attempting all the while to pass through the window toward the source of illumination. With many species this may often continue until the death of the insect from exhaustion and lack of food.

[2] AMERICAN NATURALIST, vol. 39, pp. 157–171, 1905.

Such are the results of experimentation where the transparent sheet of glass has been allowed to change the normal conditions of environment. Let us suppose, however, that the fly be allowed to pass out of the window into a more nearly natural environment. It immediately flies into the open, but does not endeavor for any length of time to continue its positively phototropic movements. Once unrestrained it is soon again following the normal pursuits of its particular species, which in the case of the aforementioned Drosophila is principally to locate decaying vegetable matter which will be suitable for food, breeding, and oviposition. It is evident in this case that the universal and quick response of the Drosophila to light when confined is due to some added factor in the experiment which I hope to point out on a later page.

Another paragraph in the same paper refers to results obtained under still more unnatural conditions.

> "The exposure of Drosophila to light of high intensity is accompanied by an increase in the kinetic effect. Under the influence of the highest intensity used, that of a 250 c.p. arc light at 40 cm., the muscle reflexes of an insect become very rapid and violent, and the directive influence of the light seems inhibited."

When we realize that these insects are as quick as ourselves to appreciate sudden changes in light and shade at short distances, it is not astonishing that they are unable to orient themselves under such startlingly unnatural conditions, placed only sixteen inches from an arc light, and their behavior here can not be compared with their reactions to normal daylight or sunlight. In fact the perversion of instinct induced by electric arc lights is a common experience with many nocturnal insects which are attracted in countless numbers, while their normally phototropic diurnal relatives are disturbed scarcely at all by the presence of the lights.

This too, is a matter of common experience, which has found expression in the adage of the moth and the flame. Most of the *Lepidoptera heterocera* are negatively phototropic, venturing out at dark and concealing themselves

from the light during the day, yet the proximity of an unnaturally brilliant light quickly upsets their normal instincts, and they are irresistibly attracted, although the appearance of the moon or the dawn affects them in no such manner.

Another tropism which is easily investigated by experimental observation is geotropism, and the agreement reached by a number of workers is that many insects when confined in an unnatural environment are negatively geotropic. To quote again from the same paper on Drosophila:

> "Gravity has a directive effect upon the active insect which is negatively geotropic, that is, the insect moves away from the center of the earth."

Such is indeed the action of almost any insect, particularly an active species or a flying one when placed in any sort of a receptacle where it is deprived of food, or where it can not enjoy the freedom to which it is accustomed. It immediately flies or crawls upward, and usually will repeat the process almost indefinitely if for any reason it finds itself again at the bottom. Since it always goes to the top of the jar if not attracted in another direction by other stimuli, negative geotropism is taken to be one of its normal attributes.

This negative geotropism, however, becomes an absurdity as soon as we attempt to apply it in a general way to insects in their natural environment. Crawling insects do not congregate at the tops of objects in their environment, and neither do flying insects approach high altitudes, far from the surface of the earth. After their first escape from unnatural restraint, their negative geotropism vanishes as quickly as did their positive phototropism. The effect of any sudden and unnatural disturbance on the action of a flying insect is very easy of observation and is experimentally tested many hundreds of times during a season by any active collector of insects. Take, for example, a common bumblebee, which on account of its large size can be easily followed by the eye

as it passes from flower to flower, often traversing a considerable space in a nearly straight line toward a particular plant whose location may be known to it through past experience. Thus it continues along, sometimes rising slightly or flying lower, but exhibiting no movements whatever which could be attributed to geotropism or phototropism.

Let it be caught in the collector's net, however, and it immediately develops the negative geotropism, flying wildly about and seeking to ascend. If the net be kept inverted it will not escape until it accidentally drops out as a result of flying at the cloth of the net or of losing its foothold in crawling upward. Once out, it soars upward perhaps a short distance, and then resumes its former occupation.

Do these actions of the fly and the bee when confined, which are characteristic of other insects as well, represent their normal tropisms?

It has been usually assumed that they do, and several ingenious explanations have been suggested which endeavor to show why phototropism and negative geotropism become inactive in nature after certain periods, since the logical result of their continued action never presents itself to observation.

From the behavior of species in nature, these are most certainly not normal and are evidently caused by the conditions of the experiment. The most probable explanation of their appearance is that they are the expression of an instinct to seek the open whenever disturbed. In nature this freedom can always be obtained by flying upward and toward the light, that is to say, by phototropic and negatively geotropic movement which carries them away from all obstacles. Such a reflex in response to disturbances is a very valuable one and is no doubt maintained by natural selection, since it automatically offers an avenue of escape from disturbing conditions or danger.

In some species this reflex is in another direction, and these exceptions are most instructive in support of this

idea. Bees of the parasitic genus Cœlioxys when caught in the net almost invariably fly downward at the first impulse, being thus positively instead of negatively geotropic. A reason for this adaptation can be suggested from a knowledge of their habits. Graenicher[3] has recently shown that Cœlioxys enters the nests of other bees to lay its eggs. Thus in the event of its discovery by the rightful owner of the nest, it may drop to the ground with much better chances for escape than it would otherwise have.

Tiger beetles of the genus Cicindela are active fliers, but are more at home on the ground, consequently when covered by the net they never rise on the wing, but invariably attempt to escape on the surface of the ground, which they can readily do if the net does not fit very closely. Their actions can thus be traced directly to an adaptation.

From any unbiased review of such facts, I think it will appear that we can not hope to make wholly satisfactory progress along the line of interpreting insect behavior by means of studying their responses to stimuli in the laboratory, unless this be done with careful reference to their habits and behavior in nature, and in relation to the various external factors of their environment.

[3] *Bull. Wisconsin Nat. Hist. Soc.*, vol. 3, p. 162, 1905.

# THE EVOLUTION OF TERTIARY MAMMALS, AND THE IMPORTANCE OF THEIR MIGRATIONS

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## THIRD PAPER.[1] MIOCENE EPOCH.

AFTER having investigated the migrations of the *Eocene* and *Oligocene* epochs (*Comptes rendus,* 6 novembre, 1905, et 12 mars, 1906), I will now consider those of the *Miocene.*

C. MIOCENE FAUNA.—I. Lower Miocene (*Burdigalian*), fauna of the *sands of the Orléanais:* principal localities (Neuville-aux-Bois, Marigny, Rebréchien, Fay-aux-Loges, Beaugency, Tavers, Les Barres; Chevilly, Neuvilly, Artenay, Ruan, Chilleurs, Suèvres, Pontlevoy, Thenay, Blasois, Chitenay; Manthelan, etc.), and of the *limestone of Montabuzard,* underlying the sands.—The marine deposits of Eggenburg and Linz (Lower Austria), of the *"Muschelsandstein"* of Bruttelen, Macconens, La Molière, Bucheggberg (Switzerland), of Saint-Nazaire-en-Royans (Drôme), of the white Molasse of Angles (Gard), of Horta de Tripas near Lisbon.—Fauna of the fissures of the *Solenhofen* quarries.

1. *Local Evolution.*—Continuance of Tapiridæ (Paratapirus), of some genera of Rhinocerotidæ (Aceratherium, Diceratherium), of Chalicotheriidæ (Macrotherium), of Anthracotheriidæ (Brachyodus becoming extinct), of Suidæ (Palæochœrus, Hyotherium), of Tragulidæ (Hyæmoschus), of Cervulinæ (Palæomeryx, Dicrocerus), of Castoridæ (Steneofiber), of Cricetinæ (Cricetodon), of Lagomorph Rodentia (Prolagus), of Talpidæ (Talpa), of Tupaiidæ (Galerix), of Canidæ (last of

[1] Extract from the *Comptes rendus des séances de l'Académie des Sciences,* t. CXLIII, p. 1120 (séance du 24 décembre, 1906). Translated by Johanna Kroeber. First and second papers, Eocene and Oligocene, in the February and March numbers of the NATURALIST.

Cephalogale), of Amphicyoninæ (Amphicyon), of Mustelidæ (Stenogale, Palæogale, Stenoplesictis), of Lutrinæ (Lutrictis, Lutra), of Felidæ (Pseudælurus, Machairodus).

2. *Very Important African or Afro-Asiatic Migrations* of Proboscidea (Mastodon, Dinotherium), of Antilopinæ (Protragocerus), of certain Cervulinæ (Micromeryx), of some Rhinocerotidæ (Teleoceras, Ceratorhinus), of some Suidæ (Chœrotherium, Listriodon), and of anthropoid apes (Pliopithecus).

3. *North American Migration* of Equidæ (Anchitherium).

II. Middle Miocene (*Vindobonian,* divisible into three substages: *Helvetian, Tortonian, Sarmatian*). Corresponding to these three substages are three mammalian faunæ, grading into one another by almost imperceptible transitions. These assemblages may be denoted as follows, the names being derived from those localities in the sub-Pyrenean basin where each is typically represented: (1) *horizon of Sansan,* (2) *horizon of Simorre,* (3) *horizon of Saint-Gaudens.*

1. *Horizon of Sansan.*—Principal localities: Sansan, Jegun (Gers), calcareous marls of the Loire (Pontlevoy, Sainte-Maure, Manthelan); marine Molasse of the environs of Romans (pont de l'Herbasse, Bren, Clérieux); marine Molasse of Suabia (Baltringen, Rammingen, Heggbach, Hausen; Niederstozingen, Süssen, Ursendorf, Hochgeland); of the lignites of Styria (Eibiswald, Göriach, Wies, Voitsberg, Gamlitz, Parschlug, Neufel) and of Lower Austria (Leoben, Leiding, Feisternitz, marine sands of Grund at Guntersdorf); Georgengsmund (Bavaria), Engelswies (Baden).

2. *Horizon of Simorre.*—Principal localities: Simorre, Bonnefond, St. Cristan, Tournon, Villefranche d'Astarac, l'Ile-en-Dodon (Gers); Saverdun (Ariège); marine deposits of Mirabeau (Basses-Alpes), of Sorgues (Vaucluse), of Romans (Drôme); Steinheim, Nordlingen, Ries, Althausen, Urlau (Suabia); Hohenhoven (Baden); intra-

Alpine basin of Vienna (Dornbach, Vordersdorf, Fünfkirchen, Loretto, Bruck-a.-Leitha, Breitenbrunn, Margarethen, Mannersdorf, Neudorf); Abstdorf, Franzensbad (Bohemia); Wosskressensk (Russia); Pesth, Ssoskut (Hungary); Trauenzinen (Silesia), Krivadia and Gyulu-Mendru (Transylvania).

The rich "terrain sidérolithique" ("Bohnerz") of La Grive-Saint-Alban (Isère), of Mont Ceindre (Rhône), of Pretty near Tournus (Saône-et-Loire), of Gray (Haute-Saône), of Mösskirch, Genkingen, Willmardingen, Heuberg, Melchingen, Jungnau (Suabia) belong in large part to this horizon.

3. *Horizon of Saint-Gaudens.* — Principal localities: Valentine, Saint-Gaudens, Montréjau (Haute-Garonne); Delsberg, le Locle, La Chaux-de-Fonds, Vermes, Oeningen, Ellg, Kapffnach, Weltheim (Switzerland); Hœder, Dinkelscherben, Günsburg, Diessen, Reichenau, Reisensburg, Dasing, Fraising, Tutzing, Stätsling, Reichertshofen, Frontenhausen, Flinz of Munich, Sankt Georgen (Bavaria); Hernals, Heiligenstadt (Vienna basin); Mt. Bamboli (Tuscany); San Isidro near Madrid; Aveiras de Baixo (Portugal); Kriwoi-Rog, Nicolaieff, Sébastopol, Tiraspol (Russia).

1. *Local Evolution.*—Continuance of Equidæ (Anchitherium), of Tapiridæ (Paratapirus), of Rhinocerotidæ (Aceratherium, Teleoceras, Ceratorhinus), of Chalicotheriidæ (Macrotherium), of Suidæ (last representatives of Hyotherium and Chœrotherium; Listriodon; finally Sus itself), of Tragulidæ (Hyæmoschus), of Cervulinæ (Dicrocerus, Micromeryx, last representatives of Palæomeryx), of Antilopinæ (Protragocerus), of Proboscidea (Mastodon, Dinotherium), of Theridomyidæ (last remnants of Theridomys), of Myoxidæ (Myoxus), of Sciuridæ (Sciurus), of Castoridæ (Steneofiber), of Cricetinæ (Cricetodon), of Lagomorph Rodentia (Prolagus, Lagomys), of Talpidæ (Talpa, Proscapanus, Scaptonyx), of Myogalidæ (Myogale), of Tupaiidæ (last of Galerix and Lantanotherium), of Soricidæ (Sorex, Crocidura).

last Dimylidæ (Plesiodimylus), of Erinaceidæ (Erinaceus, last of Palæoerinaceus), of Chiroptera (Rhinolophus, Cynonycteris, Vespertilio, Vesperugo), of Canidæ (Galecynus), of Amphicyoninæ (Pseudocyon, Hemicyon, Dinocyon, last Amphicyon), of Mustelidæ (Haplogale, Stenogale, Pseudictis, Mustela, Palæogale, Proputorius, Trochictis, Trochotherium), of Lutrinæ (Lutra, Enhydriodon), of Viverridæ (Viverra, Herpestes, Progenetta), of Felidæ (Machairodus, Hyænailurus, last Pseudælurus, first true Felis).

2. *Migration of South American origin* (by way of Africa) of the Hystricidæ (Hystrix).

3. *Migrations, Probably Asiatic-African,* of the Ursidæ (several branches, Pseudarctos, Hyænarctos, Ursavus), of the catarrhine monkeys (Oreopithecus), and anthropoids (Dryopithecus).

III. Upper Miocene (*Pontian*). *Fauna of Pikermi.*—Principal localities: Pikermi (Greece); Isle of Samos (Asia Minor); Maragha (Persia); Tchernigow, sands of Balta, limestone of Odessa and of Groussolowo (Russia); Manzati (Roumania); Baltavar, lignites of Baróth-Kôpecz (Hungary); Eppelsheim (Germany); Siebenhirten, Congeria gravels of the Vienna basin, vicinity of Eggenburg (Lower Austria); Mont Luberon, Visan (Vaucluse), Aubignas (Ardèche), Puy-Courny (Cantal), Saint-Jean-de-Bournay, La Tour-du-Pin, La Trappe de Chambaran (Isère), Montmirail, Tersanne (Drôme), La Croix-Rousse and Sainte-Foy à Lyon, Ambérieu, Soblay, Saint-Jean-le-Vieux (Ain), rocher du Dragon at Aix-en-Provence, Montredon (Hérault), Estavar (Cerdagne), Orignac (Hautes-Pyrénées); Concud (Spain); Archino (Portugal); Grasitelli (Sicily).

To the same horizon belongs the greater part of the "terrain sidérolithique" of Salmendingen, Melchingen, Trochtelfingen, Ebingen, Undingen, Heuberg (Suabia).

1. *Local Evolution.*—Continuance of Tapiridæ (Tapirus), of some groups of Rhinocerotidæ (Ceratorhinus,

last Aceratherium and Teleoceras), last Chalicotheriidæ (Chalicotherium), of Suidæ (Sus, last Listriodon), of Tragulidæ (last Hyæmoschus), last Cervulinæ (Dicrocerus, Micromeryx), of Castoridæ (last Chalicomys, earliest Castor), of Hystricidæ (Hystrix), of Canidæ (Simocyon), last Amphicyoninæ (Dinocyon), of Ursidæ (Hyænarctos, Ursavus), of Mustelidæ (Mustela, Promeles, Promephitis), of Viverridæ (Ictitherium), of Felidæ (Machairodus, Felis), of anthropoid apes (Dryopithecus, Anthropodus).

2. *North American Migrations* (perhaps by way of Asia) of one of the Equidæ (Hipparion) and of the Leporidæ (Lepus).

3. *Afro-Asiatic Migrations* of some Rhinocerotidæ (Atelodus), of Cervidæ (Capreolus), of Giraffidæ (Helladotherium, Palæotragus, Camelopardalis, Samotherium), of several groups of Antilopidæ (Palæoryx, Gazella, Palæoreas, Protragelaphus), of Ovidæ (Criotherium), of Hyænidæ (Lychyæna, Hyænictis, Hyæna), of Muridæ (Acomys), of catarrhine monkeys (Mesopithecus).

# ON XEROPHYTIC ADAPTATIONS OF LEAF STRUCTURE IN YUCCAS, AGAVES AND NOLINAS[1]

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ZOOLOGY and botany are now so separated, and for a worker in one field to venture into the other is so unusual that it may not be out of place to state my reasons for presenting this paper, which are as follows:

1. Practically all of the material was worked up in 1903–4, and since I shall not have opportunity to complete the study I wish to make this part available.

2. I wish to emphasize the importance of the results of plant physiology to the zoologist. Many of those phenomena now brought into such prominence in zoology (*i. e.*, trophisms, heteromorphosis and the mutually antitoxic action of sodium and calcium) were discovered in plants and later studied in animals. Likewise the study of the water economy of desert plants may ultimately throw some light on similar processes in animals that are subjected to constant (*i. e.*, Dermestes) or periodic lack of water (*i. e.*, rotifers). The cutin of plants and the chitin of animals play similar rôles, and it may be that the carbohydrate and mucoid (?) water-storing substances in plants have analogues in animals.

I am indebted to Dr. W. L. Bray for suggesting and directing this study, and for procuring the material, most of which he obtained from Langtry, Texas and from the Missouri Botanical Garden.

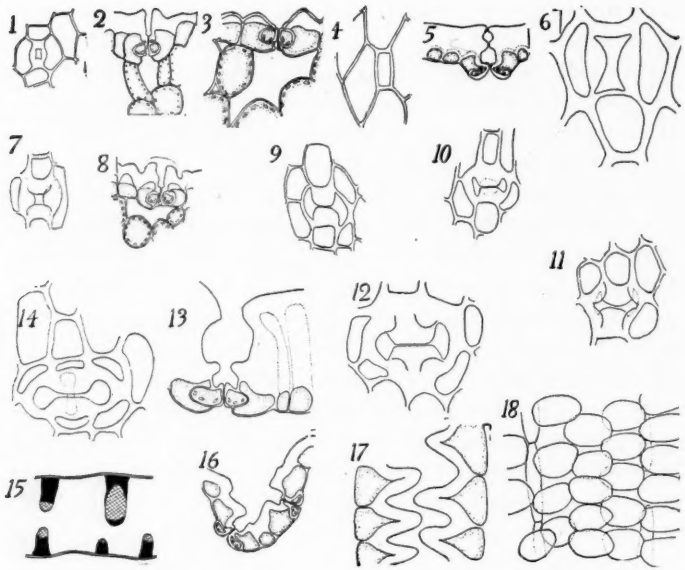
*Methods.*—The most serviceable method for investigating cell walls was free-hand sections stained in chlorio-

[1] Contribution from the Botanical Laboratory of the University of Texas under the direction of Dr. W. L. Bray.

dide of zinc. A freezing microtome might have been of service. Celloidin did not penetrate thoroughly in six weeks and was abandoned. Thin paraffine sections were cut, but where bundles were isolated in succulent tissue they usually tore through part of the latter. The experimental side of the subject was not touched.

Yucca and its allies are mostly xerophytic plants that have been modified along various lines to adapt them to their xerophytic habitat. Root, stem and leaf are succulent, thus serving for water-storage tissue. The leaves are closely set in a rosette, thus protecting one another against too great insolation and transpiration. In Agave, Hesperaloe, Dasylerion, Nolina and some species of Yucca the stalk is very short, thus enabling the leaves to shade the ground over the larger roots and protect them from drying. The leaves are especially modified: the epidermis is greatly thickened and heavily cutinized, the skeleton more or less rigid, the stomata sunken beneath the surface, either singly or in grooves, and the assimilation tissue many layers thick.

*The Respiration System.*—The simplest type of stoma in this group is probably found in *Yucca aloifolia tenuifolia* (Figs. 1 and 2). In this species the guard cells are not sunken much beneath the general epidermal surface, but the very thick epidermis is pierced by an air passage nearly square in cross section (Fig. 1), leading to the slit between the guard cells. Beneath the guard cells is an intercellular air space of considerable size leading into small intercellular air spaces. The epidermis is heavily cutinized and the cutin extends inward through the stoma and lines the upper part of the air space beneath. The assimilation tissue is palisade near the epidermis; but the cells show a tendency to arrange themselves radially around the vascular bundles. There are large intercellular air spaces in the interior of the leaf. Stomata of like character were found in *Yucca aloifolia, Y. aloifolia marginata, Y. aloifolia conspicua, Y. gloriosa* and *Y. gloriosa flexilis.*




(In diagrammatic cross sections mechanical tissue is black and vascular tissue cross striated.)

FIG. 1. Stoma of *Yucca aloifolia tenuifolia*—surface view.
" 2. The same in cross section of leaf.
" 3. Stoma of *Agave yuccæfolia* in cross section of leaf.
" 4. Same—surface view.
" 5. Stoma of *Dasylerion texanum* in cross section of leaf.
" 6. Stoma of *Agave americana*—surface view.
" 7. Stoma of lower side of leaf of *Yucca recurvifolia*—dotted lines represent portions of two teeth that are covered by the other two.
" 8. Same in cross section of leaf.
" 9. Stoma of *Yucca radiosa*—surface view.
" 10. Stoma of *Y. rostrata*—surface view—passage beneath teeth shown by dotted line.
" 11. Stoma of *Y. glauca*—surface view.
" 12. Stoma of *Agave victoria reginæ*—surface view.
" 13. Stoma of same in cross section of leaf.
" 14. Stoma of *A. schotti*—passage beneath teeth shown by dotted line.
" 15. Diagram of part of cross section of leaf of Nolina sp.? from Mexico.
" 16. Groove in cross section of leaf of *Dasylerion glaucophyllum*.
" 17. Groove in tangental section of leaf of *Nolina texana*.
" 18. Assimilation tissue in longitudinal section of same.

In *Agave yuccæfolia* the cutinized layer of the epidermis is thinner and the air passage leading to the stoma proper is much shorter than the preceding and is elongated parallel to the long axis of the leaf (Figs. 3

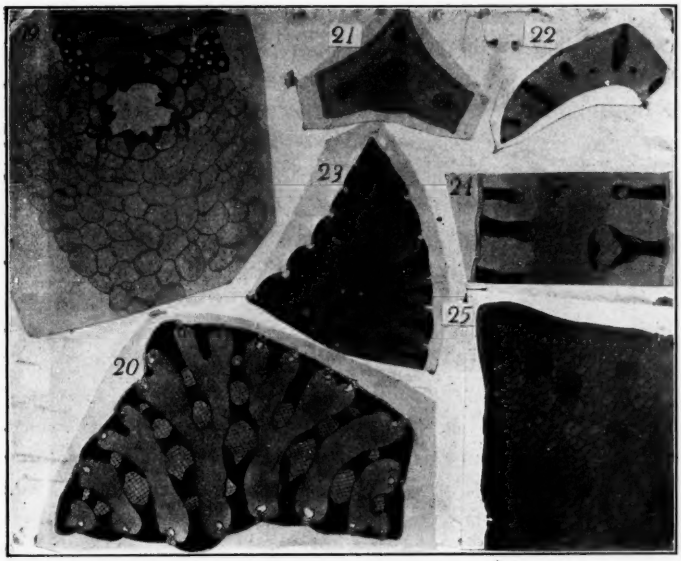



FIG. 19. Groove in cross section of same—the cutinized portion of epidermal cell walls shown darker than other cell walls; mechanical tissue black.
" 20. Cross section of leaf of same.
" 21. Cross section of leaf of young seedling of same.
" 22. Same after two years growth in damp greenhouse.
" 23. Part of cross section of leaf of *Hesperaloe parviflora*.
" 24. Part of cross section of leaf of *Dasylerion wheeleri;* the middle of the leaf is filled with large celled storage tissue.
" 25. Part of cross section of leaf of *Agave strida*—photograph.

and 4). Beneath the cuticle is a thick layer of water-storing cellulose. A series of forms with this type of stoma arranged in order of progressive sinking of the stoma would include: *Hesperaloe præciosa, Yucca de smetiana, Y. rupicola, Agave strida* and *Dasylerion texanum.* In the last named (Fig. 5) the supra-stomal passage is divided into two dead air spaces, and the stomata occur in slight longitudinal furrows. The ridges between are braced heavily with mechanical tissue.

In *Agave americana,* the century plant (Fig. 6), the sides of the elongated supra-stomal passage are produced into lips, constricting it in the middle.

In *Dasylerion wheeleri* a second similar constriction occurs half way down this passage, so that in cross section it appears like *Dasylerion texanum*. In this species the epidermal cells are produced into papillæ.

Going back to the simple type of stoma found in *Yucca aloifolia* we can trace variation in another direction. In the stomata of the lower side of the leaf of *Yucca recurvifolia* the four sides of the supra-stomal passage are produced into lips; those parallel to the long axis of the leaf being beneath the others (Figs. 7 and 8). On the upper side of the leaf the lips are not as well developed, and are all in the same plane, as are also those of *Yucca australis* and *Y. treculiana*.

In *Yucca radiosa* (Fig. 9) and *Y. constricta* only two of the lips are developed, so that we have an opening somewhat like the ones in *Agave americana* rotated through a right angle. In *Yucca rostrata* the lips have developed so as to close the opening in the middle, leaving only an opening at each end (Fig. 10).

In *Y. glauca* (Fig. 11) four additional lips have developed above the two as in *Y. radiosa*, and the accessory cells have sunken considerably beneath the level of the other epidermal cells.

In *Agave victoria regina* (Fig. 12) the presence of six lips is accompanied by the meeting of one pair and by the division of the supra-stomal passage into two dead air spaces (Fig. 13). Here the epidermal cells secrete an immensely thick layer of reserve or water-storing (?) cellulose under the cuticle (Fig. 13). The leaf is very succulent and the vascular bundles are confined to the middle layer.

In *Agave schotti* the shape of the supra-stomal passage changes greatly as we go inward. On the surface it is elongated at right angles to the long axis of the leaf, while farther down it is elongated parallel to the long axis (Fig. 14).

Besides being sunken singly between the level of the

epidermis the stomata are often placed in rows at the bottom of a groove. These grooves are very slight in Nolina sp.? from Mexico (Fig. 15), *Dasylerion wheeleri* and *D. texanum*. They are deeper in *D. glaucophyllum* (Fig. 16) and *Hesperaloe parviflora*.[2] They are very deep and guarded with teeth in *Nolina texana*[3] (Figs. 17 and 18) and Nolina sp.? from West Texas. The formation of grooves is directly associated with the bracing of the epidermis with beams of mechanical tissue (Fig. 20) along the ridges between the grooves. In Nolina sp.? from Mexico (Fig. 15), *Dasylerion wheeleri* (Fig. 24), *D. texanum* and *Hesperaloe parviflora* (Fig. 23) these beams are free in the interior of the leaf, but in *D. glaucophyllum* and *Nolina texana* (Fig. 20) the beams of one side usually meet and fuse with those of the other, forming a rigid support for the epidermis that prevents any dorso-ventral shrinkage of the leaf on drying. The only shrinkage that does occur closes the grooves and thus is a further check to transpiration. Another characteristic associated with the presence of these longitudinal transpiration grooves is a peculiar modification of the air passages in the assimilation tissue, which reaches its greatest development in the Nolinas. In the forms without grooves there is an irregular air space below the stoma, from which lead minute air spaces in all directions. With the development of grooves is associated a more effective arrangement of these air spaces, so that rapid respiration of the deeper tissue is effected without the devotion of much of the volume of the leaf to air space. If we imagine the groove represented in Fig. 17 in tangential section, as being placed horizontally with the opening upward, the assimilation tissue in the form of lamellæ one cell thick is suspended from the inner surface of the groove. Air diffusing in through the stomata enters the narrow spaces between the lamellæ and almost immediately penetrates to the center of the leaf. If we

[2] Bray, '03.
[3] Bray, '03.

imagine a lamella removed from the leaf when turgid, the cells composing it would be rounded on their free surfaces. If such a lamella were placed on another so that some of its cells rested on the apices of the cells of the one underneath, we should get a condition similar to that in *Nolina texana* (Figs. 18 and 19) and allied forms. Fig. 18 is drawn from a thick longitudinal section of the leaf, and the irregularities in the lamellæ obscure their distinctness. The lamellæ are additionally supported by columns of elongated cystoliths running parallel to the long axis of the leaf and connecting one lamella with another.

*Mechanical and Vascular Tissue.*—The leaves of Yucca and its allies are covered by a very thick cutinized epidermis which is quite stiff and supports the soft tissue beneath, thus forming an exoskeleton. In smooth leaves the bundles are distributed through the interior of the leaf, in thick leaves being arranged in several rows (Fig. 25). Each bundle is composed of vascular tissue supported by a large amount of mechanical tissue, and thus the bundles form an internal skeleton. In those leaves in which grooves occur the ridge between two grooves is heavily braced within with mechanical tissue (Fig. 23). These braces often extend inward until each fuses with a bundle (Fig. 23) and in some species all the bundles are attached to the inner edges of these braces (Fig. 15). In *Dasylerion glaucophyllum* and some species of Nolina (Fig. 20) the braces of one side of the leaf usually fuse in the middle with those of the other side, making a very rigid structure.

*Relation of Habitat to Structure of Stoma.*—The complexity in structure of stoma in these forms lead Dr. Bray to suggest that I see whether there was any correlation between the structure of the stomata and the aridity of habitat. I found that there was in all except those that had the supra-stomal passage much elongated in the long axis of the leaf. *Yucca aloifolia, Y. gloriosa* and their

varieties have a supra-stomal passage nearly square in cross section (Fig. 1) that goes straight down to the stoma, and these species inhabit coast lands which, although hot, are humid. In *Y. australis, Y. treculiana* and *Y. recurvifolia* the supra-stomal passage is guarded by four lips (Fig. 7) and these species inhabit a region from the Gulf coast to the dry interior of the United States and Mexico. In *Y. radiosa* and *Y. constricta* the supra-stomal passage is closed in the middle (Fig. 9) and these species inhabit southern Arizona, western Texas and adjacent country. In *Y. rostrata* two widely separated openings lead into the supra-stomal passage (Fig. 10), and we find this plant in the deserts of northern Mexico. In *Agave victoria regina* we find a similar structure with the addition of four small lips (Fig. 12) and we find this plant also in the deserts of northern Mexico (Coahuila). In *Yucca glauca* we find a structure similar to the preceding save that the two lower lips are slightly separated (Fig. 11), and this plant inhabits the slightly less arid lands from South Dakota to New Mexico and North Texas. In *Agave schotti* the supra-stomal passage is compressed in one axis (Fig. 14) and a little lower down is compressed at right angles to the first (Fig. 14, dotted line) and we find this plant in the deserts of southern Arizona. Finally, the Nolinas, whose stomata are placed in deep grooves guarded by interlocking teeth, cling to crevices in the rocks in western Texas and northern Mexico, where not only is the air dry and the sun hot, but there is extremely little soil to hold a store of moisture.

*Development of Leaf in Nolina Texana.*—The very young leaf in the adult plant is not deeply grooved as in Fig. 19 or 20 and the mechanical tissue is not well developed. The formation of grooves is associated with the formation of ribs of mechanical tissue supporting the epidermis between the bands of stomata, and by growth inward uniting with the vascular bundles, thus forming

girders extending through the leaf in a dorso-ventral direction. The epidermis bulges out along the lines of attachment of the girders and sinks in between them. The epidermal cells bordering the grooves thus formed grow out into long interlocking teeth. The teeth get longer and the groove narrower as the leaf develops, thus protecting the stomata from the dry air.

In the very young seedling the leaf is somewhat triangular in cross section (Fig. 21) with a vascular bundle in the center and one in each lateral angle and a bundle of mechanical tissue in the midrib. The epidermis is cutinized at this early stage.

I kept a seedling in a greenhouse of the University of Pennsylvania about two years. The leaves did not grow stout as in plants from the natural habitat and I think the increased moisture and diminished insolation affected the thickness of the leaves (Fig. 22). The leaves were very thin; the mechanical tissue uniting with the vascular bundles formed beams connecting the dorsal with the ventral epidermis between the bands of stomata, but the grooves only began to develop. It seems remarkable that a plant so adapted to xerophytic conditions should be able so quickly to adjust itself to a moist atmosphere, and I think the subject merits further investigation.

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# THE BIOLOGICAL LABORATORY OF THE BUREAU OF FISHERIES AT WOODS HOLE, MASS.: REPORT OF WORK FOR THE SEASON OF 1907

DR. FRANCIS B. SUMNER

DIRECTOR OF THE LABORATORY.

## I. RECENT IMPROVEMENTS IN EQUIPMENT, ETC.

1. Two rooms upon the third floor of the laboratory building have been reconstructed so as to serve for the reception of the specimens comprising the local reference museum. These last were moved from their former inadequate quarters at the commencement of the summer, and have been subjected to a thorough overhauling.

2. A considerable number of standard scientific works were purchased by the bureau as the nucleus of a permanent reference library; though it is true that only a beginning has thus far been made. The already great collection of reprints and other miscellaneous donations, together with the reports of the scientific departments of this and other governments, has steadily increased. It was found, however, that the publications of many of our foremost American biologists were scarcely represented on the shelves of the library. With a view to remedying this serious lack, a circular was sent by the director to about three hundred American men of science, chiefly biologists, asking for contributions. A considerable number of these men responded liberally, and many hundreds of pamphlets and bound volumes have been received. It must be added with regret, however, that many others among those addressed have not yet thought it worth their while to place their writings in an institu

tion conducted solely for the public welfare, and offering free facilities each year to a large number of biologists.

3. A steam drying apparatus was purchased, at a total cost of over three hundred dollars, for use in experiments upon the methods of preparing various marine foods. Owing to serious delay on the part of the manufacturers, this apparatus was unfortunately not installed until late in the season.

4. Running fresh water was introduced into each of the large investigation rooms upon the second and third floors of the building, and enameled iron sinks were likewise installed in these rooms.

5. A contrivance was designed and constructed for the purpose of de-aerating the salt-water supply of the laboratory and aquarium.

6. The entire floor of the main laboratory room (162 square yards) was covered with a layer of heavy linoleum.

7. Electric table lamps, with parabolic reflectors, were substituted for the hanging lamps formerly used in the investigation rooms.

8. The supply rooms for apparatus and chemicals were greatly extended, and many improvements were effected by carpentry throughout the building.

## II. Broader Lines of Investigation

1. *Biological Survey.*—Much progress was effected during the summer, as well as during the preceding winter, in the preparation of the report upon the biological survey of local waters. It has furthermore been necessary to extend this work through the present winter; and the director is again in residence at Woods Hole, engaged in the completion of this project. At the present time it may be stated that the plotting of the distribution charts, several hundred in number, has been nearly completed by Mr. J. W. Underwood; the compilation of an annotated list of the local fauna and flora (based both upon original observations and published records) is not

far from finished; the physical data (temperature, etc.) are being tabulated; and preparatory steps are being taken toward the statement of generalized results and conclusions. During the summer it was found necessary to repeat the temperature and salinity determinations of preceding years. The steamer *Fish Hawk* was employed for this purpose and recently standardized instruments only were used. In this work the director was ably assisted by Mr. D. W. Davis. Careful thermometry revealed temperature conditions which do much toward explaining the distribution of certain forms of life, especially of those well-known boreal types which just enter the region. This problem seemed of sufficient importance to justify another extensive series of temperature and density determinations at the commencement of the present winter, and these have therefore been made by the director, with the assistance of the crew of the *Phalarope*. A third series of observations is contemplated early in March; and possibly another at the commencement of the summer.

The *Fish Hawk* was also employed in doing considerable supplementary dredging; and the in-shore stations of Buzzards Bay, which, owing to an accident to the *Phalarope,* had been left unfinished in 1905, were now completed with the aid of the latter vessel. It is perhaps worthy of mention that the parasitic gastropod mollusk, *Stilifer stimpsoni* Verrill was taken for the first time (so far as recorded) in this region; and that the rare brittle star *Amphioplus abdita* (Verrill), which was recently made the subject of a special note in *Science*[1] by Dr. H. L. Clark, was dredged at no less than three stations.

With one or two exceptions, all past collections derived from the dredging operations have been reported on by the specialists to whom they were referred. More than half of the catalogue of fauna and flora has been submitted in manuscript form to these same taxonomic

[1] January 24, 1908.

experts for revision of nomenclature and other points. It is hoped that the entire report may be completed in the rough before the expiration of the coming summer.

As usual, a fish trap was maintained in Buzzards Bay, at a point not far distant; and the customary seining trips were made for the supply of laboratory needs, as well as to furnish data regarding the occurrence of species. As a fact of especial interest in relation to the local fauna may be mentioned the entire lack, during the past season, of the gulf-weed, and the accompanying stragglers from tropical waters, which frequently form such a striking feature of the marine life during the latter part of the summer.

2. *Studies of Marine Foods.*—Investigations have for several years been in progress, directed toward the utilization of certain marine organisms of apparently high food value, which have, notwithstanding, been hitherto neglected by our population. The "smooth" dogfish, the squid,[2] and the salt-water mussel have thus far received most attention at this laboratory. An arrangement was entered into with the "mess" of the Marine Biological Laboratory, whereby certain foods were prepared according to definite directions and served at certain of the dining tables. It was thus possible to obtain the opinions of a considerable number of persons as to the palatability of the articles in question. As already stated, a steam drying apparatus has been installed at this station as an important auxiliary to these experiments. Messrs. I. A. Field and C. L. Alsberg are engaged upon both the economic and the scientific aspects of this problem. Professor Field has already reported[3] upon certain features in the bionomics of the dogfish and some other unutilized fishes, but much work remains to be done, on both the industrial and the chemical phases of the subject.

[2] It is here worth mentioning that two representatives of a Japanese produce establishment spent the summer on Cape Cod, taking steps toward the establishment of a plant for the drying of squid for exportation to their own country.

[3] Bureau of Fisheries Document No. 622, issued 1907.

3. *Deaeration of the Laboratory Water Supply.*—The "gas disease" of fishes, especially as manifested in the aquaria at the Woods Hole station, has, in past years, been the subject of extensive investigations by Gorham and Marsh.[4] These two writers presented convincing evidence that the cause of this malady lay in the super-saturation of the salt-water supply with air. The latter was shown to be forced into solution under pressure, during the process of pumping, so that the water which passes into the distributing tanks is "charged" with air, in much the same manner as soda-water and other carbonated beverages are charged with carbon dioxid. It is a familiar fact that such beverages quickly become "flat" if left to stand in an open vessel; and that the discharge of the gas is facilitated by agitating the liquid. Marsh found that in this principle lay a ready means of preventing the troubles arising from the super-saturation of the Woods Hole water supply. If the water, before its entrance into an aquarium or fish tank, were allowed to splash through a perforated pan, or merely to fall from a height as a fine jet, the evils of the gas disease would be diminished or altogether prevented. This method has since been generally adopted at the laboratory in connection with the large aquaria employed for display purposes, as well as with the smaller ones used for scientific experiments. It has commonly been necessary to employ the smallest stream of water practicable, allowing it to fall from a height, and commonly causing it to pass through a perforated pan, or to trickle over a board or other flat surface. Indeed, there have frequently been occasions when a strong stream, introduced beneath the surface of the water in a small aquarium, would prove fatal within a day or less, even to hardy fishes.

Such a state of affairs has obviously been a serious drawback to the work of the laboratory, which often

[4] Bulletin U. S. Fish Commission, Vol. XIX (1899), pp. 33–37; Report U. S. Fish Commission for 1903 (1905), pp. 93–98; Report of the Bureau of Fisheries for 1904 (1905), pp. 343–376, pl. I–III.

demands that fishes shall be kept under observation, in a healthy condition, for days or weeks. Some method of treatment was deemed advisable which should be applicable to the water supply as a whole. Thus far, no attempts to prevent the entrance of air into the pump, along with the water, have been permanently successful. The wooden suction-pipe, through which the pump formerly received its supply of sea-water, was replaced, early in 1903, by a metal one, the assumption being made that the porous condition of the former was responsible for the trouble. Indeed, Marsh and Gorham, writing during the following year, declare that "the replacement of the old suction pipe with a new impervious one abolished all signs of the gas disease at Woods Hole." But the malady was again rife during the summer of 1905, and has given much trouble during the seasons of 1906 and 1907. In the absence of definite information as to the present source of the air in the water, the most promising mode of attacking the difficulty seemed to be the construction, on a large scale, of a *deaerator,* which should operate on the same principle as the pans and boards before employed for individual aquaria. Accordingly a series of five wooden trays was built, these lying in a zig-zag series, one above the other, and having a total bottom area of about 10,000 square inches, thus bringing a large surface of water into contact with the air. Perhaps the most effective factor in the case, however, is the splashing of the water in its descent from one trough to the other and from the lowermost of these into the supply tank below. From the latter the water is distributed to the laboratory.

This deaeration apparatus was not constructed until late in the past laboratory season, but the results of the tests already made seem well worth recording. The fatal effects of the water from the local supply had been conspicuous throughout the summer. It may be mentioned, by way of example, that in one wooden tank in the hatching room twenty tautog died in a single day, apparently

from this cause alone. In the display aquaria the fishes had fared pretty well, thanks to the use of perforated pans, which were suspended several feet above each tank. The water was in no case allowed to enter below the surface, as experience had shown that the result would have been disastrous. The deaeration apparatus was first put into use on August 31, and two days later the pans over these aquaria were removed, a full head of water being allowed to enter below the surface in each. This condition was maintained until September 23. During this period of twenty-one days no deaths occurred beyond those occasional ones to be expected in a large miscellaneous collection of living fish. No symptoms of the gas disease were noted, either in the presence of surface "blebs," or in the occurrence of "pop-eyed" fishes. The collection seemed in particularly good condition, and the absence of the splashing water overhead made it possible to keep the premises much more dry and neat.

The natural inference from these facts was that the deaerator had fulfilled its requirements perfectly. But before forming definite conclusions on this point, it was necessary to perform the control experiment of throwing the apparatus out of the circuit, and using the salt water just as delivered by the pump. This was done on the afternoon of September 23. The water supplying the aquaria was allowed to enter below the surface as before. On the following day (September 24) bubbles were noted upon the surface of some of the fishes, either in the mucus or beneath the epidermis. From records made throughout the ensuing twelve days, it appeared that out of 85 fishes, belonging to 18 species, which were present at the time the process of deaeration was discontinued, 13, or more than 15 per cent., died within the ensuing six days; while within the first twelve days 15 others, or nearly 18 per cent., manifested more or less marked symptoms of the gas disease. Almost exactly one third of the stock had accordingly been killed or obviously injured.

## III. SEVENTH INTERNATIONAL ZOOLOGICAL CONGRESS

One of the prominent features of the program for the entertainment of the congress was a visit to Woods Hole on Sunday, August 25, when the members were welcomed jointly by the Marine Biological Laboratory and the Fisheries Laboratory. After a lunch served in the "mess" hall of the former institution, the party was carried to New Bedford on the U. S. Fisheries steamer *Fish Hawk*. One drag with the dredge was made *en route* by way of demonstration. On the preceding evening an informal smoker was tendered by the research staff of the Fisheries Laboratory to the local scientific colony and to such of the foreign delegates as had already come to Woods Hole in response to a special invitation. Thirteen of these visitors[5] were housed for the night in the residence building of the station. A few of the most eminent of the foreign delegates, including Hubrecht, Bateson, von Graff and some others, had spent a week or more at Woods Hole prior to the visit of the congress; not, however, as the guests of this laboratory.

## IV. INDIVIDUAL RESEARCHES

Of the twenty-five or more persons employed in various capacities on behalf of the laboratory, thirteen may, from the nature of their work, be ranked as investigators, the others serving as assistants, janitors, etc. Fourteen volunteer (unpaid) investigators likewise held tables and carried on independent lines of research. These twenty-seven investigators represented 11 states and 21 educational institutions,[6] ranging from New Hampshire to Michigan and Virginia. A detailed statement of individual researches is given below.

The hospitality of the station was likewise extended to a number of gentlemen who are not strictly to be enrolled

[5] Messrs. Derjugin, Golovine, Heymons, Koshewnikov, Kusnezov, Le Souëf, Maximow, Metalnikoff, Nedrigoiloff, Samssonow, Wladimiroff and two others (record lost).

[6] Each being accredited to the institution in which he had taught or studied during the preceding academic year.

among those conducting investigations in the laboratory during the past season. Among these are to be named the Hon. K. Gupta, of Bengal, who was making a study of American fisheries methods on behalf of his government; Messrs. G. Asaya and T. Miyake, who were seeking information in regard to the local occurrence of the squid; and Professors W. A. Locy, Henry F. Nachtrieb and S. P. Sigerfoos, who visited Woods Hole briefly at about the time of the zoological congress.

Carl L. Alsberg, M.D., instructor in biological chemistry, Harvard Medical School.—The greater part of Dr. Alsberg's work consisted in the collection and preparation for analysis of various marine animals which are either not used, or little used, as foods in this country. The complete analysis of such material was deferred until the winter months, when better facilities for analytical work would be available than it is possible to provide at Woods Hole. The work actually done at Woods Hole was to determine the water content of the different materials, as well as the proportion of soluble proteid, etc. The other analyses are now being carried out in Boston. As a result of this work, it has become evident that in order to obtain reliable information concerning the food value of many of these forms it is necessary to study the extractives. As is well known, the extractives of ordinary meats have but little food value. For some of the lower forms, notably the dog fish, this is true to an even greater degree, because this fish contains large quantities of urea dissolved in the blood plasma and in the body fluids. In order to arrive at a correct estimate of the food value of such an animal, it is necessary to determine by accurate methods the urea content, and perhaps also that of the other extractives. Concerning the extractives of other forms at present under investigation, for instance the squid, nothing at all is known, and it will be necessary to make a study of them before we can estimate the food value of this mollusk. In addition to this line of work,

which has immediate practical value, various other investigations were undertaken, or at least the material for such investigations was collected. The study of the blood of the horse-shoe crab was begun, and two researches have been subsequently completed in Boston, both of which were presented at Chicago during the present winter, one before the American Society of Biological Chemists, and the other before the American Physiological Society. The first deals with the study of the blood-clot of this animal; the second started with a study of the enzymes of the serum and has led indirectly to interesting results concerning the guajac reaction of peroxydases. Another investigation, the material for which was collected at Woods Hole, has also been finished subsequently. This is a study of the vitelline contained in the eggs of the spiny dog-fish. This vitelline has proved to be very similar to that which may be obtained from hens' eggs. Finally, an examination was undertaken, but not yet completed, into the nature of the red pigment contained in the chromatophores of the skin of the squid.

Charles B. Bennett, graduate student, Brown University, (1) took part in the work of the biological survey, being engaged in a search for certain marine organisms concerning which additional data were required, (2) assisted Dr. Alsberg and Professor Field in some of the work above described.

Walter B. Cannon, A.M., M.D., professor of physiology, Harvard Medical School.—*The Movements of the Alimentary Canal in the Dog-fish.* Peristaltic waves were seen to pass over the lower third of the cardiac end of the stomach, but they did not pass on to the pyloric end. Along the narrow pyloric portion the waves were more frequent than on the cardiac portion. Three movements were seen in the spiral valve: (1) A segmenting movement, starting anteriorly as a constriction, which was replaced by a constriction one centimeter below, and this

by another one centimeter below that, etc., until the whole intestine was traversed. When the series had passed three or four centimeters from the starting point, a new series began. (2) A movement starting posteriorly and passing forward, which consisted in a local shifting of the wall towards the left, *i. e.*, clock-wise with reference to the axis of the valve viewed from behind. As shown by small holes cut in the wall, the shifting of the wall towards the left was accompanied by a shifting of the inner folds towards the right. The effect must be a thorough mixing of the food between the two surfaces. (3) A large general shifting of the valve forwards, and with a right rotation through about 180°. This was caused by a great sheet of smooth muscle lying in the mesentery between the genital gland and the spiral valve.

Joseph F. Clevenger, M.A., acting professor of chemistry and biology, Wheaton College, Wheaton, Ill.—*The Life History of Zostera marina and Ruppia maratima.*

Harold S. Colton, M.A., graduate student, University of Pennsylvania.—*How "Fulgur" and "Sycotypus" eat Oysters, Mussels and Clams.* The work, so far as performed at Woods Hole, consisted of a series of experiments and observations on the food of Fulgur and Sycotypus (*Busycon carica* and *B. canaliculata*), supplementing some which were begun at the University of Pennsylvania during the preceding winter. There had previously been no complete account of the taking of food by those gastropods. Stimpson (1860) and Ingersoll (1884) have mentioned their food; the former not completely and the latter not correctly. The present studies dealt with the kind and amount of the food and their manner of taking it. (1) Although pieces of chopped oyster were found to stimulate these mollusks, the latter were never observed to eat them. *B. canaliculata* ate living Mya, Ostrea and Mytilus, but refused Venus. *B. carica* accepted Mya, Ostrea, Mytilus, Modiolus, Ensis and Venus,

and devoured one of each. (2) It was frequently found that one individual ate two oysters or clams in a day; there usually being a long period of rest between meals, the animal remaining buried nearly all the time, sometimes for as much as six weeks. (3) The character of the erosion, noticed on the odontophore, indicates that these mollusks are not shell borers. (4) When clams (Mya) are the objects of assault, no difficulty is encountered in gnawing out the soft parts, since the shells of the latter gape slightly. The mussel and oyster, on the other hand, are taken by surprise. The attacking gastropod thrusts the margin of its own shell between the valves of that of the prey, devouring the soft parts at leisure. In the case of the "round clam" (Venus), *B. carica* uses yet another method of attack. Holding the bivalve in the hollow of its foot it brings the margin of its own shell against the margins of that of its prey. By the contraction of the columellar muscle, the two are brought into such forcible contact that a small piece is chipped from the Venus shell. This is repeated many times, the process lasting from seven hours to three days, with the result that the crevice between the two valves is enlarged to such an extent that the gastropod can devour its victim. (5) It is possible that the two species of Busycon do not inflict so great damage upon oyster or clam beds as has previously been reported. Field observations alone can settle this point, however.

Edgar D. Congdon, M.A., Austin teaching fellow, department of zoology, Harvard University, conducted investigations upon the fauna of the brackish waters in the neighborhood of Woods Hole. A number of these ponds were studied intensively, collections being made of their fauna and flora, and determinations of density and temperature being taken. A series of other ponds was likewise visited for purposes of comparison. Mr. Congdon also acted as librarian of the laboratory, and considerable time was devoted by him to classifying and cataloguing

the now rather unwieldy collection of miscellaneous reprints.

Bradley M. Davis, Ph.D., past assistant professor of botany in Chicago University, finished during the summer the catalogue of the marine algæ, together with a section of the report dealing with the distribution of algæ and Zostera in the deeper waters of the bay and sound. Much of this manuscript had been written during the preceding spring, Dr. Davis having spent the months of April and May at the laboratory. The catalogue will contain more than 250 species of algæ, with records of their distribution and seasonal habits; and will include a list of the stations at which they were dredged. An introductory section on the general characteristics of the algal life of Buzzards Bay and Vineyard Sound has since been written, and the manuscript covering the botanical side of the survey is now practically complete, except for such editing as may be necessary to make the botanical and zoological portions conform in arrangement and style. An important part of the summer's work in botany was the completion of maps showing the distribution of 75 species of algæ which grow in the deeper waters of the bay and sound. It is expected that the most important of these maps will be published in connection with the catalogue, since they show, much more clearly than is possible in a mere description, the striking features in the distribution of the most characteristic species.

Donald W. Davis, professor of biology, Sweet Briar College, Sweet Briar, Va.—(1) *An Investigation of the Effects of Various Conditions acting at the Time of Impregnation upon the Size and Vigor of Fish Embryos.* For the time being, attention was restricted to the effects of various *temperatures,* and *Fundulus heteroclitus* was selected for experimentation because of its convenient spawning period. Each lot of eggs, taken from a single

female, was divided into equal parts. These parts were then fertilized by milt from a single male at temperatures differing from each other by 5°, 10°, 15° or 20° C. After a few minutes the two parts were again brought under identical conditions and so kept until hatching. At the expiration of a certain period, when practically all of the living embryos had hatched, all were fixed by the aceto-sublimate-formalin method, which was found to leave them well straightened. Careful records of mortality, rate of hatching, etc., in the different lots were kept. Measurements to be made upon the embryos, with a view to determining the tangible effects of such differences in treatment, are not yet complete. (2) A study of the alleged interference in branchial circulation resulting from the transfer of fishes from salt to fresh water, and *vice versa*, was also taken up. The conclusion of Bert and Mosso that such interference occurs in consequence of a clogging of the branchial capillaries by distorted blood corpuscles, was thought to be worth testing in view of recently published work by the director of the laboratory upon some other effects of changes in salinity. The common smooth dog-fish (*Mustelus canis*), the scup (*Stenotomus chrysops*) and the killifish (*Fundulus heteroclitus*) were experimented upon, the first two named being species which succumb quickly when transferred to fresh water, while the last named is commonly able to survive for some days in fresh water. The hypothetical clogging of the branchial vessels in these species was tested by passing physiological salt solution through the conus arteriosus at definite pressures, and the gills were then fixed for microscopical examination. Results immediately apparent revealed no such contrast as the statements of both Bert and Mosso would lead one to expect between fishes taken directly from salt water and those dying in fresh water. Further work will be necessary before a more definite statement of the results can be made.

Irving A. Field, professor of chemistry and biology, Western Maryland College, conducted experiments, to which allusion has already been made, with a view to testing the food value of certain hitherto unused marine animals. These were tested in respect to their palatability and digestibility by serving them, properly cooked, to numerous persons, who passed judgment on the quality of the food and the effects subsequently observed. Determinations of the chemical composition and nutritive value of the materials in question were, as has already been stated, undertaken by Dr. Alsberg. Various methods used commercially for the preservation of fisheries products (drying, salting, pickling, etc.) were applied to the forms studied. Statistics relating to the abundance of each species and the cost of preparing it for the market were also kept.

John H. Gerould, Ph.D., assistant professor of zoology, Dartmouth College, devoted a few days to the collection and study of a rare and hitherto undescribed species of sipunculid. Although two dredging trips were made with the *Fish Hawk* and the *Phalarope* for this express purpose, but a single specimen was obtained, which, however, was observed in a living condition, an opportunity which was regarded as of considerable value.

Charles W. Hargitt, Ph.D., professor of zoology, Syracuse University.—(1) *A Monographic Synopsis of the Anthozoa of the Region.* But little systematic attention has been devoted to the local representatives of this group since the work of Verrill and Smith more than thirty years ago. It has been the purpose of Dr. Hargitt to secure as full collections as the facilities at hand rendered possible, and to carefully review the group with reference to the species, their distribution, habits, development, etc. This work is now nearing completion so far as its laboratory phase is concerned, and will soon be ready for publication. At least one new species has been

found, and one or more have not as yet been identified with certainty. Some additional facts as to distribution and habits are likewise to be reported. (2) *Systematic Determinations of Local Cœlenterate Animals, as related to the Biological Survey now in Progress.* The survey has brought to light a number of new species of hydroids and medusæ, and a few hitherto quite unrepresented in the fauna of the region. Some account of these may be found in some recent "Notes on the Cœlenterate Fauna of Woods Hole."[7] Others remain to be determined. Dr. Hargitt accompanied many of the dredging expeditions made, and thus personally collected most of his specimens in the living state, as they came up in the dredge. Opportunity was thus afforded for obtaining data as to color, etc., which are of much importance in such determinations. (3) The manuscript of the catalogue of local fauna and flora, so far as this relates to the Cœlenterata, was criticized and revised as to nomenclature. (4) Some living specimens of the fresh-water medusa, Limnocodium, were received from the Bureau of Fisheries. A brief notice of these has already appeared in *Science* (November 8, 1907). A fuller account of this most interesting medusa is ready, and will appear in the near future.

George T. Hargitt, teacher of zoology, Syracuse (N. Y.) High School (now graduate student in Harvard).—*Studies of the Embryology of the Hydromedusæ.* The work on the embryology of the cœlenterates has been most often limited to two phases, viz., the place of origin of the germ cells and development of the medusa or gonophore; and the late cleavage of the egg, with the formation of the germ layers and the development of the planula and polyp. While attention has been so largely confined to the early cleavage and maturation of the egg, the results have been rather unsatisfactory and inconclusive, and often conflicting. The work under way is an

[7] *Biological Bulletin*, January, 1908.

attempt to supply the missing or less known phases of the early development of the cœlenterate egg, and especially that of the Hydromedusæ.

John D. Haseman, M.A., graduate student, University of Indiana.—*Studies of the Reactions of the Gastropod Litorina litorea to Stimuli.* Experiments were conducted, both in the laboratory and in the field, with a view to determining the conditions and stimuli which were responsible for the movements of these mollusks and the positions chosen by them. It is believed by the writer that Mr. Haseman has already prepared for publication a paper embodying the results of these studies.

William B. Herms, A.M., Ohio Wesleyan University (now fellow in zoology, Harvard University).—*A Comparative Study of Palæmonetes.* The habits, post-embryonic development and other facts in the natural history of the common local prawn, *Palæmonetes vulgaris,* were studied in relation to similar observations already made upon the related *Palæmonetes exilipes* of Lake Erie. Interesting points, both of similarity and of difference, were brought to light. A very close relationship between the two species undoubtedly exists. Several attempts were also made to acclimatize larvæ to higher and lower degrees of salinity.

William E. Kellicott, Ph.D., professor of biology, Woman's College, Baltimore.—*Biometric Studies of the Dog-fish* (*Mustelus canis*). The season was spent in the collection of data bearing on the general problems of correlation, growth, etc., in the dog-fish. A quite complete series of measurements, including about 30 characters, internal as well as external, was made upon about 300 individuals. Dr. Kellicott is at present working over these data and examining into the rate of increase in weight of the brain and viscera. Some interesting facts have revealed themselves, and it is believed that a paper embodying these will be ready in the near future.

Charles R. Knight, American Museum of Natural History, New York City, was engaged, as has been the case for several summers, in portraying pictorially some features of the local sea life. Mention may be made in particular of a tiger-shark (*Galeocerdo tigrinus*), and a dusky shark (*Carcharinus obscurus*). Of the latter, a specimen over ten feet in length was taken in the laboratory's fish trap, and was kept alive for a few days in the shark-pool belonging to the station. The lobster, blue crab and scup also received attention, a large canvas being devoted to a group of the last.

Edwin Linton, Ph.D., professor of biology, Washington and Jefferson College.—(1) Besides examining such fishes as were available among those taken in the fish trap of the Bureau in Buzzards Bay, a preliminary study was made of a large amount of material from fishes and fish-eating birds, collected during the preceding nine months by Mr. Vinal N. Edwards. In agreement with the experience of previous years was the fact that new habitats were found for species already known, and new or unrecorded species were added to the list of those previously known. Thus new species or new habitats were recorded for 21 species of fish. Adult specimens of *Tetrarhynchus bicolor* were encountered for the first time. They were found in the stomach of a dusky shark. Scoleces of this species had, however, been found in this and other hosts during previous years. The pigment which gives the characteristic color to the head and neck of this cestode was not dissolved by the killing fluid (chrom-acetic-formalin), and has not been decolorized by the alcohol in which the worms are preserved. (2) Of the pathological and diseased conditions which were noted, an interesting one is the case of an abnormal growth of the swim-bladder of a scup. This, when first seen, was a slender, white, vermiform object about two millimeters in diameter lying among the muscles of the side. It was at first thought to be a cestode, examples of which occa-

sionally penetrate the muscular tissue of their hosts. Upon tracing it forward, it proved to be a lateral prolongation of the anterior end of the swim bladder. At its origin it corresponded in structure to the swim bladder, but at its posterior (*i. e.*, distal) end it was rather firm and the walls were thickened. The alcoholic specimen, which has contracted somewhat, is 60 millimeters in length. (3) Butterfish were examined on five occasions for the flesh parasite described in the Bulletin of the Bureau of Fisheries.[8] The proportions of infected fishes were rather less than in previous years. (4) Considerable attention was given to the parasites of the puffer (*Spheroides maculatus*) with a view to preparing a special paper on the entozoa of that fish. (5) The preparation was begun of tables of the distribution of the parasites of fishes based upon collections made by Dr. Linton, at Beaufort, Bermuda, Tortugas and Woods Hole. These tables have since been completed and sent to the Bureau of Fisheries at Washington. (6) A beginning has also been made in the collecting of parasites from invertebrate hosts for the purpose of securing stages in the life history of those parasites of fishes whose early stages are found in invertebrates.

Albert J. May, A.M., instructor in the Boys' High School, Reading, Pa., made observations upon the medusæ of various local hydroids, and collected material for future study. *Corymorpha pendula,* which was especially sought for, on account of obscure facts in its life history, unfortunately proved to be very rare.

Hansford MacCurdy, Ph.D., professor of biology, Alma College, devoted most of his time to the study and tabulation of results obtained during the preceding summer relating to the hybridization of echinoderms.

William J. Moenkhaus, Ph.D., associate professor of physiology, University of Indiana, continued studies,

[8] Vol. 26, pp. 111–132.

begun some years ago, upon the hybridization of fishes belonging to widely separated genera and families. Such cross-fertilized eggs did not commonly hatch, or even develop far, but an interesting range of abnormalities was produced. A few experiments in cross-fertilizing certain invertebrates were likewise undertaken.

Raymond C. Osburn, Ph.D., instructor in zoology, Barnard College, Columbia University, was occupied chiefly in the preparation of a report upon the local marine bryozoa, basing this work for the most part upon collections made in the course of the biological survey during the past five summers. On account of the great abundance and almost universal distribution of many of these animals locally, the need of such a monograph has been much felt. Dr. Osburn has already found a considerable number of species which are new to the region, as well as discovering errors in the previous identification of certain common local forms.

Jacob Reighard, Ph.D., professor of zoology, University of Michigan, experimented upon certain features of the behavior of *Fundulus heteroclitus;* likewise compiled results obtained earlier in the summer at the Carnegie station at Tortugas, where experiments had been performed with the object of testing the alleged warning coloration of various brilliantly tinted tropical fishes.

Russell Richardson, graduate student in the University of Pennsylvania (now assistant in the department of comparative physiology, Harvard University).—*Response of Limulus Muscle to the Electric Current.* The two large lateral tail muscles were generally used. Both constant and interrupted (induced) currents were employed; and the stimulus was applied either by wires or by non-polarizable electrodes. Endeavor was made to find out whether there was more than one form of curve to be derived from induced shocks, as had been found by some

workers; but all such attempts gave negative results, only one form of curve being obtained. The contraction is very rapid, and the height of the curve varies, within certain limits, as the strength of the stimulus. The relaxation is rapid at first, but later takes place more slowly. Summation is more or less regular. With constant current there were generally obtained the usual stimulations at the make and break of the circuit. The form of the curves varied greatly, however, according to the direction in which the current traversed the muscle. The weak constant current caused a marked relaxation of the muscle, only when passing through it in an ascending direction. Fatigue in Limulus seems more or less regular. As it progresses, there is a noticeably greater interval between the contraction and the relaxation. The latter also becomes much slower. After this stage, the height of contraction gradually diminishes until no response at all is obtained.

George G. Scott, A.M., instructor in biology, College of the City of New York.—(1) *The Effect of Poisons, at Different Temperatures, on Fundulus heteroclitus.* Sixteen experiments are recorded. In each case two lots of fish were used, one lot being kept at the temperature of the laboratory, *i. e.*, about 70° F., while the other lot was kept at a lower temperature, *i. e.*, about 50° F. Different dilute solutions of a variety of organic and inorganic poisons were used. In eleven of these experiments it was distinctly shown that the effect of the poison was greater at the higher temperature; in four, the result showed no difference; while in one, the result was opposite to the first named effect. (2) *The Effect of Change in Density of the Water on the Blood of Fundulus heteroclitus.* It has been recently shown by Sumner that there may occur a passage of fluids into or out of the bodies of teleost fishes when the density of the medium to which they are accustomed has been sufficiently changed. This has been proved by demonstrating the occurrence of changes of

weight, and by other means. It seemed worth while to ascertain what effects, if any, such changes of water density have upon the blood. The results of a few typical experiments are here stated. Hæmacytometer determinations were made upon fishes subjected to different conditions. The mean blood count of a number of specimens of *Fundulus heteroclitus* in natural sea water was found to be 2,700,000 red corpuscles per cubic millimeter. Sea water contains about 3.5 per cent., by weight, of salts in solution. In an experiment in which the salt content of the water was increased to over 6 per cent. by the addition of sea-salt, the proportion of corpuscles had increased to about 3,500,000 per cubic millimeter. In the case of another lot of fishes which were placed in 1,500 cc. of sea water, to which 30 grams of sea-salt had been added, it was found after six hours that the number of corpuscles was 2,800,000 per cubic millimeter. In yet another lot which were placed in 1,500 c.c. of sea-water plus 60 grams of sea-salt, the blood count, at the end of six hours, gave 3,000,000 corpuscles. In a case in which 120 grams of sea-salt were added to 1,500 c.c. of sea-water the blood count gave 3,900,000 per cubic millimeter. A number of fishes were placed in sea water artificially strengthened to the point of containing about 9.5 per cent. of salts. After one hour it was found that the fishes had lost in weight, while the blood counts of two specimens averaged 2,800,000; at the end of two hours, a further loss in weight was noted in the remaining fishes, and in two specimens the average number of corpuscles counted was now 3,434,000 per cubic millimeter. Fishes which were placed in distilled water and subjected to the hæmacytometer test an hour and a half later yielded about 2,000,000 corpuscles to the cubic millimeter. In two experiments with distilled water there was at first a *decrease* in the number of corpuscles counted, then a gradual *increase* up to the normal, which increase later passed above the normal. The question as to whether or not the blood is diluted by the osmotic influx of water

can likewise be investigated by determining whether the freezing point of blood serum from a fish which has been kept in fresh water is higher than that of blood serum from a fish taken from its normal medium. Although experiments of this sort had already been performed by a number of competent investigators, it seemed worth while to make the test again. This was impossible to do in the case of Fundulus on account of the small amount of serum obtainable. The experiment was carried out, however, upon *Mustelus canis*, the "smooth dog-fish."[9] Five determinations were made with the blood serum of fishes taken from normal sea water, and five with blood serum of fishes that had been kept in fresh water for an hour. These experiments agreed in showing that the freezing point of serum from fishes kept in fresh water is much higher than that of fishes taken from sea water. It was thus demonstrated that the blood of fishes may be diluted by a sojourn in fresh water, and support is given to the view that the change in the number of corpuscles counted was due to dilution or concentration of the blood. The last mentioned experiment upon Fundulus, in which distilled water was used, suggests that after the first dilution of the blood, due to the physical process of osmosis, there occurred a physiological reaction on the part of the organism, the excess of water being expelled from the blood. That it remains in the body of the animal, however, is shown by the persistent increase in weight.

Francis B. Sumner, Ph.D., director U. S. Fisheries Laboratory, Woods Hole, Mass.—(1) The supervision of the *biological survey;* (2) experiments in the deaeration of the local salt-water supply; (3) an investigation into the meaning of the color variations of *Litorina palliata* Say (carried on jointly with James W. Underwood). The first two of these lines of investigation have already been discussed in the more general part of the paper; a

[9] The known physiological differences between elasmobranchs and teleosts can not, of course, be left out of consideration.

synopsis of the third has appeared in a recent issue of *Science*[10] and need not be repeated.

James W. Underwood, student and assistant in Olivet College, (1) assisted in the work of the biological survey, being occupied for some months in plotting out the distributions of the more frequent local species upon maps which had been printed for the purpose; (2) collected and studied the species comprising the local plankton during the spring season; (3) cooperated with the director in the above mentioned study of the color variations of *Litorina palliata*.

Ralph E. Wager, A.M., teacher of biology, state normal school, Potsdam, N. Y.—*Studies of the degenerative Changes in Hydroid Polyps under the Influence of Changed Polarity or Contact Stimuli.* Experiments were performed for the purpose of providing material in different stages of degeneration, with the object of subsequently studying not only the histology, but more particularly the cytology of the changes. Abundant material was at hand in the various species of Obelia, and a sufficient supply of the degenerating polyps was obtained to thoroughly test the killing and fixing methods, if not to satisfy the demands of the problem. Thereafter experiments were performed on Gonionemus for the purpose of obtaining regenerating tissues, with a similar intention of determining the cytological changes involved in their growth. Again a plentiful supply of material was available, and enough of the regenerating tissues was obtained to make possible a fairly thorough study.

[10] March 27, 1908.

# HEREDITY OF HAIR-FORM IN MAN

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THE hair of man shows various morphological types. Between straight hair, on the one hand, and woolly hair, on the other, there are all degrees of closeness of spiral. For convenience three intermediate grades may be recognized; *wavy,* having a very slight or open spiral involving the entire hair from root to tip; *curly,* having a closer spiral involving the distal half of the hair; and *frizzy* or *kinky,* a close tight spiral of small diameter. Now, although the conditions thus named are not discontinuous, they stand for types that are fairly well appreciated and distinguished popularly, so that in a random lot of people practically all would place a given sort of hair in the same category.

These different types of hair form are associated with certain differences of the hair on cross section as well as in its method of growth. Thus straight hair is nearly circular on cross section, while in woolly hair the cross section is elliptical and the long axis is to the short as 100:40 or 100:50. In wavy hair the proportions are as 100:60 or 70. The straight hair of the Japanese has the proportions of 100:85.

Since the hair of most mammals is straight and nearly circular on cross section, we may regard this as the basal condition and the flattened hair as a specialized form marking an advance in the *differentiation* of axes. In addition to this difference in cross section hairs differ in the form of the hair follicle, which is in woolly hair not only flattened, but curved in an arc through a quarter of a circle. "Emerging from an incurvated mould, it can only

continue to roll up outside, given especially its flattened shape; it rolls up into a spiral the plane of which, at the beginning, is perpendicular to the surface of the skin'' (Deniker '06, p. 43). As all gradations exist between straight hair and wool in other characters, so probably in the initial curvature. The intermediate nature of *waviness* is probably due to an intermediate degree of curvature beneath the skin. This curvature of the follicle, again, is a departure from the usual mammalian condition and is in the line of differentiation or advance.

We are now in a position to formulate our problem. How do the more specialized types of hair form—much flattened and much curved woolly hair and slightly flattened, slightly curved wavy hair behave in heredity toward each other and toward the nearly cylindrical straight hair?

The data for this study are derived from the same sources as those of our eye color study[1] and include the ancestral characteristics of about 500 children for two ascending generations. About 230 families are involved.

The nomenclature of hair form that collaborators were requested to employ was as follows: Straight, wavy, curly, kinky. As our cards were distributed only among whites the term ''woolly'' was not used. The terms seem to have been, for the most part, understood by the collaborators.

The first result revealed by an analysis of the pedigree data regarding hair form is that straight hair is recessive to the curved types. Thus to 70 pairs of parents both said to have straight hair were born 185 children of which we have records. Of these 167 are recorded as having straight hair; 13 ''wavy'' and 5 ''curly.'' Also 164 grandparents, both with ''straight hair,'' are said to have had 146 straight-haired children, 11 ''wavy'' and 7 ''curly.'' Knowing how liable to slip collaborators are we venture to affirm that probably not less than 98 per cent. of the offspring of straight-haired parents have

[1] *Science*, N. S., XXVI, No. 670, pp. 589–592, November 1, 1907.

themselves straight hair.[2] The genuine cases of straight-haired parents producing wavy or curly hair in the children are probably cases of imperfect dominance—or heterozygotes in which the recessive type appears to dominate. In all such cases the grandparentage contains always one or more cases of wavy or curly hair. Cases of recessive heterozygotes are not rare in the experience of students of heredity. They do not invalidate the general idea of Mendelian dominance. Striking cases of all straight-haired offspring of straight-haired parents are seen in the Bal., Bea., Bri., But., Cla., Hof., Loe., Mil., Oat., Pot., Reg., Sam., Spr. and Whe. families, each of four or more children. In these families there are 63 children altogether, and all of them have straight hair.

A second criterion of Mendelism is found in crosses of the R $\times$ DR type where a recessive is mated to a heterozygous dominant; in this case expectation is fifty per cent. of each type. Eighty matings between straight and heterozygous wavy give 61 straight and 52 curved-haired offspring, and 22 matings between straight and curly give 53 straight and 38 curved; or altogether, 116 to 90 where 103 of each is expectation (Cf. Dou-B., Got., Halz., Kar., McBr. families). There is a slight excess of recessives, probably due in part to a tendency to designate as "straight" boys whose curly hair is cut short; possibly to some cases of failure to dominate.

A third criterion is found in the crosses of the DR $\times$ DR type where two heterozygotes are mated to-

[2] The principal sources of error in naming hair form made by our collaborators are as follows: (1) Citing in males the form of the short, clipped hair instead of the youthful *long hair*. Curly hair when cut short appears as straight hair; this source of error is great in the case of the grandfathers, who are frequently deceased; (2) recording a hair form from a hazy recollection; a slightly wavy hair is often recalled as "straight." An attempt was made to get a confirmation of all doubtful cases (*i. e.*, not in accordance with the law) and in almost all cases in which a reply was received one of the two "straight" parents of curved-haired children was found actually to have curved hair. One exceptional case is that of the Hil family, where three wavy haired children came from two straight haired parents. The mother probably has curly germ cells which fail to dominate.

gether. Expectation in this case is 25 per cent. of the straight hair and 75 per cent. of the curved types—of the later 25 per cent. being pure dominants (DD) and 50 per cent. DR. Of 59 offspring of two DR parents there were actually found 22 per cent. curly, 51 per cent. wavy and 27 per cent. straight, or 73 per cent. curved to 27 per cent. straight. This again accords closely with expectation and supports the view of the essential DR nature of wavy hair (Cf. Bar., Gav., Gen. families).

All results indicate with a high degree of probability that straight hair is recessive to spiral hair; but it is probable that the spiral form may, in some cases, fail to dominate.

We have now to consider the behavior of wavy in relation to curly or kinky, *i. e.*, the lesser grade toward the greater. The statistics show clearly that wavy hair is usually, if not always, a *heterozygous* condition, and not merely an intermediate stage that is recessive to a higher stage (curly) and dominant over a lower (straight). For straight by wavy frequently gives curly (10 per cent. of cases) as well as wavy and straight. The result is in close accord with the conclusion that wavy always carries both straight and curly germ cells and when mated with single yields in the offspring an equality of straight and curved hair. Thus 113 offspring of straight by wavy parents give 54 per cent. straight and 46 per cent. curved hair. The "curly" germ cell of a *wavy*-haired person, uniting with a "straight" germ cell, usually gives the heterozygous, wavy form; but in 23 per cent. of the cases fails to do so, owing, we may say, to the unusual activity of the curly determiner. Wavy appears also when the curly germ cells of a heterozygous *curly*-haired person unite with "straight" germ cells. As in the last case, the offspring are not all wavy; indeed, the proportion of wavy is less, for 53 per cent. of the offspring are *curly*. That peculiar strength which makes a heterozygote *curly* instead of wavy tends to make its heterozygous offspring also curly instead of wavy.

We can now formulate the results of this study in their relation to human marriage, combining them in part with those obtained by us for eye color. Two blue-eyed, straight-haired parents will have only blue-eyed, straight-haired children. Two wavy-haired parents may have straight, wavy- or curly-haired children but the chances for curly hair are slight. Two curly-haired parents may have children with either straight, wavy or curly hair and the proportion of curly-haired offspring will probably be large. When one parent has straight hair and the other curly hair the offspring will all have curly hair, if the curly-haired parent is homozygous—otherwise half of their children will have straight hair and half curved. But the families of straight and wavy haired parents will probably have straight as well as wavy and curly hair, for waviness is always heterozygous.

TABLE SHOWING INHERITANCE OF HAIR FORM IN ALL FAMILIES OF TWO OR MORE CHILDREN.

c, curly; s, straight; w, wavy; k, kinky. Letters in parentheses refer to *recessive* characters; when accompanied by a ? the recessive character is inferred. Brackets are employed to designate inferred gametic constitution. ?? implies doubt whether the assigned character is correct. — means no record.

| Reference Letters. | Children. C | W | S | Parents. Mother. Father. | Nature of Mating. | Grandparents. Mother's Mother. Father's Mother. | Mother's Father. Father's Father. | Expectation. Curved. | Straight. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | s | | s | s | | | |
| Bal | | | 6 | s | R × R | s | c(s?) | | 6 | |
| | | | | w[cs] | | w[cs] | s | | | |
| Bar | 3 | 2 | 1 | c(s) | DR × DR | s | c | 4.5 | 1.5 | |
| | | | | s | | s | s | | | |
| Bea | | | 5 | s | R × R | — | s | | 5 | |
| | | | | w[cs] | | c(s?) | w[cs] | | | Mother's sibs. : |
| Beh | 1 | 6 | 1 | s | DR × R | s | s | 4 | 4 | 1 c, 1 w, 2 s. |
| | | | | s | | s | s | | | |
| Bri | | | 5 | s | R × R | s | s | | 5 | |
| | | | | s | | s | s | | | |
| But | | | 4 | s | R × R | s | s | | 4 | |
| | | | | c(s) | | s | c | | | |
| Byr | 4 | 2 | | c | DR × D | w[cs] | c | 6 | | |
| | | | | s | | s | s | | | |
| Cam | 1 | 5 | 4 | w[cs] | R × DR | s | s?? | 5 | 5 | |
| | | | | s | | s | s | | | |
| Cla | | | 4 | s | R × R | s | s | | 4 | |
| | | | | s | | s | c(s?) | | | |
| Dav | | | 2 | s | R × R | s | s | | 2 | |
| | | | | s | | s | s | | | |
| Deg | | 1 | 1 | c(s) | D × DR | w[cs] | s | 1 | 1 | |
| | | | | s | | w[cs] | s | | | |
| Dou-A | | 2 | 5 | c(s) | R × DR | c | s | 3.5 | 3.5 | |
| | | | | c(s) | | w[cs] | c | | | |
| Dou-B | 2 | | 2 | s | DR × R | w[cs] | s | 2 | 2 | |
| | | | | w[cs] | | s | s | | | |
| Dra | 2 | | | k | DR × D | c | c | 2 | | |
| | | | | s | | w[cs] | c(s?) | | | |
| Dru | | | 2 | w[cs] | R × DR | w[cs] | — | 1 | 1 | |
| | | | | s | | s | w[cs] | | | |
| Elt | 1 | 1 | 1 | c(s) | R × DR | w[cs] | s | 1.5 | 1.5 | |
| | | | | s | | s | w[cs] | | | |
| Eny | | 1 | 8 | w[cs] | R × DR | s | c | 4.5 | 4.5 | |
| | | | | c(s) | | c | s | | | |
| Fal | | 1 | 6 | s | DR × R | s | s | 3.5 | 3.5 | |
| | | | | w[cs] | | w[cs] | c(s?) | | | Mother's sibs. : |
| Fis | 2 | 1 | 1 | s | DR × R | c(s) | s | 2 | 2 | 2 w, 1 s. |
| | | | | s | | s | s | | | |
| Fri | | | 3 | s | R × R | s | s | | 3 | |
| | | | | s | | s | s | | | |
| Fue | | | 3 | s | R × R | s | s | | 3 | |
| | | | | w[cs] | | w[cs] | w[cs] | | | |
| Gav | 2 | 4 | 1 | w[cs] | DR × DR | w[cs] | w[cs] | 5.3 | 1.7 | |
| | | | | c(s) | | s | w[cs] | | | |
| Gen | | 2 | 1 | w[cs] | DR × DR | s | c | 2.3 | 0.7 | |
| | | | | c(s) | | s | c | | | |
| Gla | 2 | 1 | 4 | c(s) | DR × DR | c | s | 5.3 | 1.7 | |

TABLE SHOWING INHERITANCE OF HAIR FORM IN ALL FAMILIES OF TWO OR MORE CHILDREN.—*Continued.*

c, curly; s, straight; w, wavy. Letters in parentheses refer to *recessive* characters; when accompanied by a ? the recessive character is inferred. Brackets are employed to designate inferred gametic constitution. ?? implies doubt whether the assigned character is correct. — means no record.

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|---|---|---|---|---|---|---|---|---|---|---|
| | | | | w[cs] | | s | c | | | |
| Gor | 2 | 3 | 6 | c(s) | DR × DR | w[cs] | c | 8.2 | 2.8 | |
| | | | | s | | c (s?) | s | | | |
| Got | | 2 | 2 | w[cs] | R × DR | s | w[cs] | 2 | 2 | |
| | | | | w[cs] | | s | w[cs] | | | |
| Gre | | 2 | | w[cs] | DR × DR | w | w[cs] | 1.5 | 0.5 | |
| | | | | w[cs] | | w[cs] | s | | | |
| $Hal_1$ | 2 | 1 | 1 | s | DR × R | s | w[cs] | 2 | 2 | |
| | | | | s | | s | s | | | *[Probably curly when grown long] |
| $Hal_2$ | 2 | | 2 | s??* | R × DR | c | s | | | |
| | | | | c(s) | | s | s?? | | | |
| Har | 3 | 1 | 6 | s | DR × R | s | s | 5 | 5 | |
| | | | | s | | w[cs] | s | | | |
| Hil | | 3 | | s | ?DR × R | s | s | 1.5 | 1.5 | |
| | | | | s | | s | c(s?) | | | |
| Hof | | | 5 | s | R × R | s | s | | 5 | |
| | | | | s | | s | s | | | |
| Hop | | | 2 | s | R × R | s | s | | 2 | |
| | | | | w[cs] | | s | c | | | |
| Huf | | 2 | 1 | s | DR × R | w[cs] | s | 1.5 | 1.5 | |
| | | | | w[cs] | | s | c | | | |
| Hur | | 3 | 1 | s | DR × R | s | c | 2 | 2 | |
| | | | | s | | s | c | | | |
| $Irw_1$ | | | 2 | w[cs] | R × DR | s | w[cs] | 1 | 1 | |
| | | | | w[cs] | | — | — | | | |
| $Irw_2$ | | 1 | 2 | s | DR × R | — | — | 1.5 | 1.5 | |
| | | | | w[cs] | | s | s?? | | | |
| Jem | 2 | 1 | | s | DR × R | w | s | 1.5 | 1.5 | |
| | | | | w[cs] | | s | w[cs] | | | |
| Ker | 1 | 1 | 2 | s | DR × R | s | s | 2 | 2 | |
| | | | | s | | s | s | | | *[Probably curly when grown long] |
| Koc | 1 | | 4 | s??* | | w[cs] | s | | | |
| | | | | c(s) | | c | s | | | |
| Lat | 4 | | 1 | s | DR × R | s | s | 2.5 | 2.5 | |
| | | | | s | | s | s | | | |
| $Loc_1$ | | | 5 | c(s) | R × DR | c(s?) | c | 2.5 | 2.5 | |
| | | | | w[cs] | | c | w[cs] | | | |
| $Loc_2$ | | | 2 | s | DR × R | s | c(s?) | 1 | 1 | |
| | | | | s | | s | c(s?) | | | |
| Loe | | | 4 | s | R × R | s | s | | 4 | |
| | | | | s | | c | s | | | |
| McBr | 2 | | 3 | c(s) | R × DR | s | c | 2.5 | 2.5 | |
| | | | | s | | c(s) | s | | | *[Probably curly when grown long] |
| Mea | 1 | 2 | 1 | s??* | | c | s | | | |
| | | | | s | | s | s | | | |
| $Mil_1$ | | | 3 | s | R × R | s | s | | 3 | |
| | | | | s | | s | s | | | |
| $Mil_2$ | | | 6 | s | R × R | s | s | | 6 | |

TABLE SHOWING INHERITANCE OF HAIR FORM IN ALL FAMILIES OF TWO OR MORE CHILDREN.—*Continued.*

c, curly; s, straight; w, wavy. Letters in parentheses refer to *recessive* characters; when accompanied by a ? the recessive character is inferred. Brackets are employed to designate inferred gametic constitution. ?? implies doubt whether the assigned character is correct. — means no record.

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|---|---|---|---|---|---|---|---|---|---|---|
| Moo | | | 2 | s<br>c(s) | R × DR | w[cs]<br>s | s<br>s ?? | 1 | 1 | |
| Mor | | | 2 | s<br>w[cs] | R × DR | s<br>— | c(s ?)<br>— | 1 | 1 | *1 sister has curly hair. |
| Mur-B | 1 | | 2 | s*<br>c(s)** | R × DR | s<br>s | s ?? ***<br>s ?? *** | 1.5 | 1.5 | **s, in manhood, 1 sister has curly hair. ***Recollection hazy. |
| Oat | | | 8 | s<br>w[cs] | R × R | —<br>— | —<br>— | | 8 | |
| Pad | | 5 | | w[cs]<br>c(s) | DR × DR | w[cs]<br>— | w[cs]<br>— | 3.8 | 1.2 | |
| Poe | | | 3 | s<br>s | DR × R | s<br>s | s*<br>s | 1.5 | 1.5 | *Confirmed by letter. |
| Pot | | | 4 | c(s?)<br>c(s) | R × DR | c(s?)<br>c | c<br>w[cs] | 2 | 2 | |
| Pre | 1 | 4 | 1 | s<br>s | DR × R | w[cs]<br>w[cs] | s<br>s | 3 | 3 | |
| Rau | | | 2 | s<br>s | R × R | s<br>s | s<br>s | | 2 | |
| Reg | | | 6 | w[cs]<br>s | R × DR | s<br>w[cs] | s<br>s | 3 | 3 | |
| $Sam_1$ | | 1 | 1 | c(s?)<br>c(s) | R × DR | c<br>w[cs] | c(s?)<br>s | 1 | 1 | |
| $Sam_2$ | | 3 | 2 | s<br>s | DR × R | s<br>s | s<br>s | 2.5 | 2.5 | |
| $Sam_3$ | | | 5 | s<br>s | R × R | s<br>s | s<br>s | | 5 | |
| Sco | 1 | | 5 | s??*<br>s | | c<br>s | s<br>s | | | *[Probably curly when long.] |
| Sho | | | 3 | s<br>s | R × R | s<br>— | s<br>— | | 3 | |
| Spr | | | 4 | s<br>s | R × R | —<br>s | —<br>s | | 4 | |
| Sto-B | | | 2 | s<br>s | R × R | s<br>s | s<br>c(s?) | | 2 | |
| Swe | | | 3 | s<br>w[cs] | R × R | s<br>w[cs] | s<br>s | | 3 | |
| Tru | 1 | 1 | 2 | s<br>w[cs] | DR × R | w[cs]<br>c | s<br>s | 2 | 2 | |
| Tuc | 1 | 1 | | w[cs]<br>s | DR × DR | w[cs]<br>s | w[cs]<br>s | 1.5 | 0.5 | |
| Voo | | | 3 | s<br>w[cs] | R × R | s<br>c | s<br>w[cs] | | 3 | |
| War-A | 1 | 1 | | w[cs]<br>s | DR × DR | w[cs]<br>c(s?) | s<br>s | 1.5 | 0.5 | |
| War-B | | | 2 | s<br>s?? | R × R | s<br>c(s) | s<br>s | | 2 | |
| Web | | 2 | 5 | s | | s | s | | | |

TABLE SHOWING INHERITANCE OF HAIR FORM IN ALL FAMILIES OF TWO OR MORE CHILDREN.—*Continued.*

c, curly; s, straight; w, wavy. Letters in parentheses refer to *recessive* characters; when accompanied by a ? the recessive character is inferred. Brackets are employed to designate inferred gametic constitution. ?? implies doubt whether the assigned character is correct. — means no record.

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|---|---|---|---|---|---|---|---|---|---|---|
| | | | | w[cs] | | s | s? | | | |
| Wel | | 3 | 7 | s | DR×R | — | c | 5 | 5 | |
| | | | | s | | s | s | | | |
| Wet | | | 2 | s | R×R | s | s | | 2 | |
| | | | | s | | — | — | | | |
| $Whe_1$ | | | 6 | s | R×R | — | — | | 6 | |
| | | | | c(s?) | | — | — | | | |
| $Whe_2$ | | 1 | 1 | s | DR×R | s | s | 1 | 1 | |
| | | | | s | | s | s | | | |
| $Wil_2$ | | | 3 | s | R×R | s | s | | 3 | |
| | | | | s | | s | s | | | |
| Zim | | | 2 | s | R×R | s | s | | 2 | |
| Total | | 110 | | 202 | | | | 123 | 189 | |

# NOTES AND LITERATURE

## ECHINODERMATA

**Renewed Interest in Recent Crinoids.**—Since the lamented death of Dr. P. H. Carpenter in 1891, the recent crinoids have received little attention as compared with the other classes of echinoderms. Aside from the obvious difficulty of securing material, this has been due to certain inherent difficulties which systematic work in this class affords. Carpenter and his successors have recognized but few genera, the largest of these being cosmopolitan in distribution, and the numerous species have appeared to be ill-defined and extremely variable. Consequently aside from A. Agassiz's great monograph on Calamocrinus, a few systematic papers by Hartlaub, Bell, Koehler, Döderlein and Chadwick, a monograph on *Antedon bifida*, by the last, and an important morphological paper, on arm-regeneration in Comatulids by Minckert, our knowledge of the recent crinoids, and particularly our understanding of the interrelationships of the subordinate groups, was, at the beginning of 1907, about where it was left by Carpenter nearly twenty years before. The cruise of the "Albatross" in the North Pacific in 1906 afforded one of her naturalists, Mr. Austin Hobart Clark, exceptional opportunities for the study of recent crinoids and recognizing the responsibility thus laid upon him, Mr. Clark has during the past year made numerous and important contributions to our knowledge.

His first paper, "Two New Crinoids from the North Pacific Ocean,"[1] gives a figure and description of a most remarkable new stalked crinoid, for which the name Phrynocrinus is proposed, and of a new species of Bathycrinus, a well-known deep-sea genus of stalked crinoids. So remarkable does Phrynocrinus appear to be that it is suggested a new family, "Phrynocrinidæ," be established for it. The characters of this family are unfortunately not suggested, and to one having only an indistinct idea of the characters upon which the already very large number of families (mostly extinct) of stalked crinoids is based, the proposal of a new family does not make a strong appeal.

On the same date, Mr. Clark published a paper on "A New

[1] *Proc. U. S. Nat. Mus.*, 32, pp. 507–512.

Species of Crinoid (*Ptilocrinus pinnatus*) from the Pacific Coast, with a Note on Bathycrinus,"[2] in which another remarkable genus of stalked crinoids is described and figured, and there is a discussion of some of the specific names used in Bathycrinus. The new genus is considered to be related to the interesting Calamocrinus which the "Albatross" collected some years ago near the Galapagos Islands.

A paper on "Crinoids of the Genus Eudiocrinus from Japan"[3] bears the same date as the two preceding. Eudiocrinus is a genus of free-swimming crinoids (comatulids) remarkable for having united radials, but only five arms. Two species were found to be common along the southern coast of Japan, and three specimens of a third, which is described as new, were also taken by the "Albatross." A summary of the genus, with a synonymy of its seven species and statements of the type-localities closes the paper. Two papers dealing with "New Species of Recent Unstalked Crinoids"[4] appeared in September and give us a little insight into the extraordinary wealth of material which the "Albatross" collected, for we have here descriptions of no less than 55 new species, of which 52 belong to the genus Antedon as used by previous writers. Mr. Clark points out that the commonly used generic name Actinometra is untenable, being a pure synonym of Lamarck's older name Comatula. As the free-swimming crinoids are now so commonly called comatulids, it is not an unwelcome discovery which thus rehabilitates Comatula. Free use is made of artificial keys in these papers, although their usefulness is impaired by their doubtless necessary limitation to the new species and two or three most nearly related forms. There is plain intimation that Carpenter's "groups" of the genus Antedon are not in all cases natural or satisfactory divisions and that a rearrangement of the species is necessary.

In his next paper, "New Genera of Recent Free Crinoids,"[5] Mr. Clark attacks this problem and shatters the old genus Antedon into eighteen fragments, entirely discarding the group arrangement of Carpenter. At first thought this seems like needlessly drastic treatment, but the more one studies Mr. Clark's reasons and results, the more satisfied one becomes that such treatment is unavoidable if we are to get at the true interrelation-

[2] *Proc. U. S. Nat. Mus.*, 32, pp. 551–554.
[3] *Proc. U. S. Nat. Mus.*, 32, pp. 569–574.
[4] *Proc. U. S. Nat. Mus.*, 33, pp. 69–84 and 127–156.
[5] *Smith. Misc. Coll.*, 50, pp. 343–364.

ships of the comatulids. Few zoologists realize how many species of recent comatulids are now known, and it may therefore be of interest to point out that while only four of the new genera proposed are monotypic, five have more than eighteen species each and one of these has over fifty. Mr. Clark's selection of new names for his genera is particularly to be commended, as all are derived from the Greek, terminate in *-metra,* and are euphemistic.

During the summer, Mr. Clark worked at the Museum of Comparative Zoölogy and some of the results of his work appeared in January in a paper, entitled "Notice of Some Crinoids in the Collection of the Museum of Comparative Zoölogy."[6] In addition to the description of eight new species, there is an important note on six-rayed crinoids, a key to the genus Bathycrinus in which eight species are recognized, a table showing the bathymetrical and geographical distribution of Bathycrinus, and finally a "Key to the genera of Antedonidæ." This key is an enlargement and slight rearrangement of the one published in October and includes two additional genera, both of which seem to be well-defined.

Not content with systematic work alone, Mr. Clark shows his interest in crinoid morphology, and the larger questions involved when the geological history of the class is considered, by a very important paper on "Infrabasals in Recent Genera of the Crinoid Family Pentacrinitidæ,"[7] in which he demonstrates, apparently beyond doubt, the presence of infrabasals in *Isocrinus decorus* and *Metacrinus rotundus.* As no less an authority than Carpenter himself "positively asserts that they do not exist in the recent Pentacrinitidæ," this discovery is very interesting.

Having found how heterogeneous a group the old genus Antedon is, Mr. Clark's attention was naturally turned next to the equally well-known genus Comatula, and the results are given in "The Crinoid Genus Comatula Lamarck; with a Note on the *Encrinus parræ* of Guérin."[8] It is interesting to know that Comatula is far more homogeneous than might have been expected and requires the coinage of no new generic names and the revival of only a single old one, Comaster. The latter however, includes 43 of the 50 species hitherto called Comatula (or Actinometra). The note on *Encrinus parræ* is important and interest-

[6] *Bull. M. C. Z.,* 51, pp. 233–248.
[7] *Proc. U. S. N. M.,* 33, pp. 671–676.
[8] *Proc. U. S. N. M.,* 33, pp. 683–688.

ing for it clearly shows that the familiar name *Pentacrinus mülleri,* which has been used for a well-known West Indian crinoid for over half a century must give way to the combination *Isocrinus parræ* (Guérin), the specific component of which antedates *mülleri* by over twenty years.

Although the genus Antedon of previous writers had already yielded him nineteen new genera, Mr. Clark's indefatigable labors convinced him that the residue left therein (some 36 species) was not a homogeneous or natural group. In his "New Genera of Unstalked Crinoids,"[9] he has analyzed it and resolved it into thirteen elements, three of which are monotypic and three contain only two species each. Although he names his new genera with his customary skill and euphony, and gives the genotype and other species of each, he does not tell us what is left for Antedon s. str., and if we attempt to figure it out for ourselves, we reach the remarkable conclusion that Antedon as now limited contains *minus* 7 species! For, in October Mr. Clark said that Antedon (in the restricted sense in which he then used the name) contained 36 species. Since October he has described two additional species, which would give him 38 species for the new genera described in April. But these 12 new genera contain a total of 45 species, and therefore Antedon s. str. must now have —7 species! Whether this discrepancy is due to the shifting of the limits of some of his earlier genera, or to species of other writers which he had previously overlooked, or to *nomina nuda* introduced in the paper under discussion, we shall leave to Mr. Clark to explain at some future time.—Besides his new genera of Antedonidæ, Mr. Clark splits Eudiocrinus into two genera which he considers fundamentally distinct, and he then proposes no less than *eight* families of comatulids, with 39 genera. As he gives no definitions, or even a key, to these families, we can not express an opinion as to their validity. We can only wonder if Mr. Clark's enthusiasm is not leading him to magnify relatively unimportant details into significant morphological differences, and blinding him to the fundamental similarities of structure which the Antedonidæ show.

The ten papers here reviewed are sufficient to convince any one that their writer is a worker of extraordinary industry and enthusiasm. More than this, however, they give promise that Mr. Clark is to become a worthy successor to Carpenter as an authority on recent crinoids. Situated where the great collections

[9] *Proc. Biol. Soc. Wash.,* 21, pp. 125–136.

of the National Museum, which, thanks to the "Albatross," probably contain the largest and finest lot of crinoids in the world, are constantly available, his opportunities are most unusual and it must be a source of pleasure and gratification to all students of echinoderms that he is living up to them so well. His work reveals unusual powers of analysis and of skill in making his distinctions tangible, as witness his artificial keys to genera and species which seem to be very usable. He is quick to see a new point in structure or a new interpretation of some point already known, and while he treats the work of Carpenter and other writers with the courtesy and consideration they deserve, he does not hesitate to point out errors or misinterpretations which they have made. If he possesses the necessary patience and persistence, there is every reason to believe that Mr. Clark's work will prove epoch-making in the history of crinoid morphology and taxonomy.

Two faults seem to the present reviewer to mar Mr. Clark's work so far, and it is greatly to be hoped that he will have the courage and self-control to eliminate them in the future. One is a tendency to rush into print on the discovery of each new fact or group of facts, and the consequent result is a multiplication of titles to afflict all future workers, and a decided weakening of the value of each of his papers. Had Mr. Clark made four papers out of the ten which have already appeared, not only would bibliographers have blessed him, but his work would at least seem to have more of the weight and dignity which its quality shows it to deserve.—The other fault is a far more serious one and appears to be the cause of whatever errors and ambiguities mar Mr. Clark's work. It is hastiness in reaching a conclusion, hastiness in grouping the conclusions reached and hastiness in preparing his results for the press. In a word, haste is Mr. Clark's besetting sin and threatens to be the source of much quite avoidable trouble. As an illustration of what is meant by this criticism, reference may be made to some points in Mr. Clark's paper, "New Genera of Unstalked Crinoids." In his introductory remarks, he corrects four or five slight errors in his earlier papers, all of which might fairly be said to have been caused by haste. Under Thaumatometra, "*Antedon ciliata* A. H. Clark, 1907 (= *Antedon tenuis* A. H. Clark, 1907)," is given as the genotype, but neither *ciliata* nor *tenuis* appear in the list of species referable to the genus. Moreover, if we go back a little we find that while *tenuis* and *ciliata* were described

in September, in October Mr. Clark substituted the name *stella* for *tenuis* as the latter is preoccupied. Now are we to understand that Mr. Clark has concluded his three names refer to a single species? If so the description of *tenuis* and *ciliata* as distinct species was, to say the least, hasty. Again, under Compsometra, we find the following bit of evidence of haste in preparation: certain characters "distinguish this species at once. The two species at present known are," etc. Evidently the first "species" should read "genus." Under Isometra, Mr. Clark says that the name *challengeri* which he bestowed on an Antedon in 1907 is a synonym because it was given "before its relation to *angustipinna* was detected." Under Pentametrocrinus attention is called to an important morphological feature of certain species of Eudiocrinus, which "seems to have escaped the notice of all subsequent workers," and yet Mr. Clark himself published, less than a year ago, quite a paper on Eudiocrinus, with description of a new species and an annotated list of all previously known ones. Finally, in concluding his paper, Mr. Clark says, "The genera of free crinoids belonging to the Comatulida may be grouped as follows," and he then gives eight families with their various genera. But we fail to find the Atelecrinidæ or the genus Atelecrinus mentioned, and we can only guess whether the genus is considered synonymous with one of those given (which hardly seems possible) or is omitted through carelessness. Now while it is true that none of these slips is serious, Mr. Clark has not hesitated to criticize other writers for very similar blunders, and their presence in his work necessarily affects our estimate of its reliability. It is of the greatest importance, if the mantle of Carpenter is to rest becomingly on his shoulders, that in his future work, Mr. Clark reveal a greater patience, a more controlled enthusiasm and a more painstaking care in the preparation of his results for publication.

H. L. C.

## ANIMAL BEHAVIOR.

**Recent Work on the Behavior of Higher Animals.**—The members of the genus Mus—the rats and mice—seem in a fair way to become the classic animals for comparative psychology, as the frog has long been for physiology. The work of the Harvard school, examined in our last review, dealt largely with these animals. The recent work of the Chicago laboratory is concentrated even more precisely on the white rat.

In his earlier work on "Animal Education," Watson had made such a general study of the behavior of the white rat as to give a survey of the problems and methods for future work. He and his collaborators have now undertaken a well-considered campaign of intensive investigation in the different phases of the rat's behavior.

The matter selected for first attack is "the determination of the relative importance of the several sensations of a given animal in its adjustment to its environment." What senses does the rat use in finding its way about and what part does each sense play? To this is devoted the main recent work from the Chicago laboratory.[1]

Watson finds, as Yerkes did with the dancing mouse, that the rat makes comparatively little use of senses that we are accustomed to think of as the all-important ones. His conclusion that sight, touch, hearing and smell play little, if any, part in the rat's finding its way about may almost receive the usual reportorial characterization of scientific results as "startling."

The method of work was to place the rat at the entrance of the complicated "Hampton Court" maze, with its many passageways and blind alleys, and allow it to find its way to the central compartment, where food had been placed. This was repeated many times, till the correct path was completely learned; many different rats were used, and a thorough study was made of the rat's method of finding its way. The questions are essentially, (1) what senses does the rat use in learning the correct path; (2) what senses does it use in following the correct path after it is learned?

To answer these questions, one or more senses were excluded, in different specimens, either by operative procedure or by other methods. The following extraordinary results were reached:

1. Blinded rats, or those studied in complete darkness, learn the path as quickly and follow it as readily as do those that can see. Even if the path is learned in the light, blindness causes no disturbance in later following it. (One rat formed an exception, finding its way in the dark only with the greatest difficulty.)

2. Rats deprived of smell and of hearing do not differ from normal ones in learning and following the correct path. This is true even when these rats *are likewise blinded.*

[1] Watson, J. B. Kinæsthetic and Organic Sensations: their Rôle in the Reactions of the White Rat to the Maze. *The Psychological Review,* Monograph Supplement, Vol. 8, No. 2, 1907, 100 pages.

3. Removal of the long vibrissæ or "feelers" on the face at first disturbed the rats greatly. But if, before testing them with the maze, the rats were allowed forty-eight hours to become accustomed to the loss of the vibrissæ, then they threaded the maze as readily as did normal rats. This was true even if these same rats were blind or without smell.

4. Altering the temperature conditions, changing the air currents in the maze, or making the feet insensitive does not disturb the rats, so that the corresponding senses seem to play no part in the behavior.

5. The evidence is strong that taste plays no part in the matter.

Apparently then we can exclude sight, touch, smell, hearing, taste and the temperature sense as factors of any importance in finding the way through the labyrinth. How then *does* the rat find its way?

Evidently the rat relies for its guidance mainly on the complex of inner sensations due to its own movements, the amount of effort it has put forth, and the like; the "kinæsthetic and organic sensations." In threading the maze, the animal learns how much effort it is to put forth going in a certain direction, which way and how much it is then to turn, how much effort to put forth in the new direction, which way to turn again, etc. It finally knows the entire path as a combination of such efforts and turns. The behavior of the rat is somewhat like that of a person who may, in the dark, walk about a house with which he is familiar, threading his way among tables and chairs, without touching them. But in man this involves many memory images of the various objects and their relative positions and distances. In the rat such images evidently play little if any part; it is mainly a matter of amount of effort, direction of turn, and the like. Watson is inclined to conclude that the rat has no such images; that the purely intraorganic sensations account for the entire behavior; that the rat uses in threading the maze no sense data from the outside, either past or present.

If this is true, then if the trained rat could be started at the entrance of the maze so as to get the proper "cue" at the beginning, and then *the entire maze lifted from the floor, so as to leave a clear space to the food in the center, the rat ought nevertheless to follow the same complex path that it follows when the walls of the maze are present.* Would this occur? Could not the experiment be tried?

While it appears conceivable that the running of the maze, after it is learned could be exclusively a matter of the inner sensations, so that the rat might follow the path even if the maze were absent, it is extremely difficult to see how this could be the case with the first learning of the maze. Our proposed experiment of removing all source of "extraorganic" sensation by doing away with the walls of the maze seems a *reductio ad absurdum;* the rat certainly would not learn the typical maze path under such conditions. How does the rat *learn* that it must put forth so much effort in a certain direction, then turn in a certain way? It would seem that for this, certain data from outside,—due either to feeling the wall with vibrissæ, or running squarely against it, or the like—are necessary. Even when the rat runs full tilt against a wall, that gives some sort of an extrinsic sensation that would seem to require consideration.

This is a point which the author does not make clear, though he seems to argue decidedly that it is possible to explain the entire behavior, both in learning and in finding the way after it has been learned, from the purely inner sensations. Does he perhaps hold that the only effect sensed by the rat, when it runs against a wall, is one of restraint, of prevention of further effort in that direction? Such a view would seem possible, if at all, only for actual collision at full speed, while cases where the rat merely feels the wall with its vibrissæ seem hardly open to this interpretation. It would have been helpful to certain readers if the author had so far recognized their obtuseness as to take up this point explicitly. In passing it may be remarked that the entire paper is written in a curiously confused and careless manner, as if it were a first draft which the author had not found time to revise. So thorough and important an investigation deserved better treatment.

A further development of the work set forth in the paper of Watson is presented in a later paper by Carr and Watson.[2] If the rat's method of threading the maze is merely to go a certain distance (as measured by the amount of effort put forth) then to turn in a certain direction, etc., without any data from outside itself, then evidently it would be greatly disturbed by altering the lengths and proportions of the passageways. Or if it is set down not at the entrance to the maze, but in the middle

[2] Carr, Harvey, and Watson, J. B. Orientation in the White Rat. *Journ. Comp. Neurol. and Psychol.*, 1908, 18, 27–44.

of one of the passages, of course a different combination of movements will be required to reach the center; a combination which it will not have learned, so that confusion would result. On the other hand, if the rat recognizes the correct turns, etc., by sight or other extraorganic senses, then less confusion need result from the changes mentioned.

The paper of Carr and Watson is an account of the behavior of the rat when the alterations above mentioned are made. When the trained rat is placed, not at the entrance of the maze, but in one of the passages, it appears confused, wanders about, then suddenly gets a "cue," and runs directly along the correct pathway to the center. The authors argue that the animal gets this cue through the intraorganic sensations. The rat wanders till it finds that it puts forth a certain amount of effort in a certain direction and then turns in a certain direction, etc.; this combination is familiar, so that the correct movements for the rest of the course are at once "set off" by it.

When certain passages of the maze were lengthened or shortened after the animal had learned the correct path, this caused precisely such disturbances as would be expected if the kinesthetic sensations are the fundamental ones. If a passage is made shorter than before, the rat runs full tilt against its end, even though this would appear to be "in plain sight." If a passage is made longer, the rat tries to turn when it has gone the usual distance; it thus runs against the side wall. If a blind passage now opens at a distance corresponding to that of a former correct turn, the rat runs into the blind passage.

After many trials in the altered maze the rat finally learns to run through it as readily and correctly as before. This result is reached after many experiences of running into ends, "nosing" along side walls, trying to turn where there is no passageway, and the like. The reader is inclined to see here an excellent opportunity for study of the transformation of cues from outer sense data into kinesthetic cues. But again the authors argue that the whole is purely a matter of the inner sensations. If they would explain clearly just how the animal gets its kinesthetic cues without aid from outer sense data; how it learns without running into the end of a passage that it must put forth only so much energy in a certain direction; or if they would demonstrate that bumping into walls, nosing along passages, and the like, gives no extraorganic sensations of any consequence,

the reader would appreciate better their argument as to the *exclusive* rôle of the inner senses. One is slightly inclined to feel that the authors are making the common mistake of weakening the effect of a demonstration of the unsuspected great importance of a certain factor, by endeavoring to maintain that it is the *only* factor.

Another factor in rat behavior is dealt with in the paper of Slonaker.[3] Watson in his earlier work had found that young rats (25 to 30 days old) learn certain operations more quickly than do the adults, and this appeared to be due to the fact that the young were more active. They tried, in a short time, all sorts of movements, and were therefore likely to hit quickly upon the "right" ones. Slonaker makes a careful study of the comparative amounts of activity in rats of different ages, in order to see how far this is correlated with the quickness of learning. A revolving cage was used, of such a character that the activity of the rats was automatically recorded. One such experiment, with several rats, lasted 25 days; another 57; another 60. It was found that, while there are great differences in individuals, both the very young rats and the old ones (age about a year) were comparatively inactive; the period of greatest activity falls in the age between 87 and 120 days. No close relation was evident between these results and those of Watson on quickness in learning.

All together, the work of the Chicago laboratory has of late been directed with unusual precision on a well-defined single line of research. And hand in hand with this work on behavior have gone studies on the nervous system, growth and life history of the rat, many results of which have been published from the neurological laboratory. Such a unified and intensive series of investigations may well serve as a model of the best method for making solid and permanent advance in comparative psychology.

H. S. JENNINGS.

[3] Slonaker, J. R. The Normal Activity of the White Rat at Different Ages. *Journ. Comp. Neurol. and Psychol.*, 17, 1907, pp. 342–359.

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